



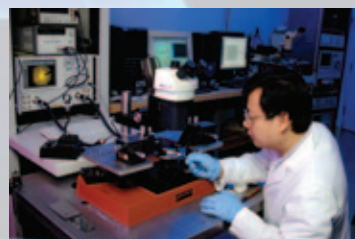
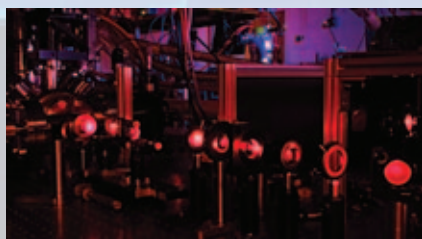
U.S. Army Research Laboratory



2009 Annual Review

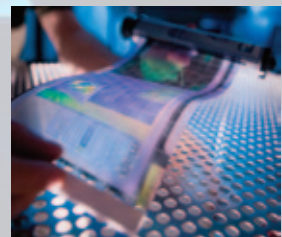
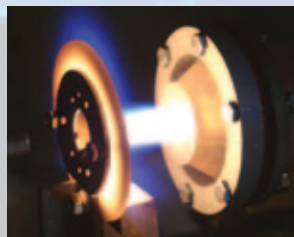
Table of Contents

Foreword	2
Overview	3
Mission/Vision	3
Organizational Role	4
Key Facilities.....	6
 The ARL Team.....	 8
Outreach Initiatives	10
Partnerships and Collaborations	12
Recognition and Awards	16
ARL Fellows.....	20
Director's Research Initiatives	21
 Capabilities.....	 22
Infrastructure	22
TPW - Technology Planning Workshop	26
Strategic Research Initiatives	28



Support to Current Operations	30
Mission Accomplishments.....	34
Extramural Basic Research	36
Networks.....	40
Human Dimension	44
Lethality	46
Mobility	49
Power and Energy.....	52
Sensors.....	55
Protection	58
Survivability/Lethality Analysis	61
From the Director	64
Glossary	66

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Foreword

John M. Miller, Director of the U.S. Army Research Laboratory

Welcome to the Fiscal Year 2009 edition of the Army Research Laboratory (ARL) Annual Review. This publication is our opportunity to provide the reader a brief look at who we are and highlight some of the significant achievements of the past year. We are a diverse organization with a wide variety of research and analysis expertise and capabilities that touch on virtually every area of scientific endeavor. What you will see here will therefore be only a representative sample of the on-going efforts of the ARL.

ARL's research continuum stretches from early, long-term, basic research to evolving new technologies to support current operations. We organize our research and analysis programs within nine Technology Focus Areas: Extramural Basic Research, Networks, Human Dimension, Lethality, Protection, Mobility, Power and Energy, Sensors, and Survivability/Lethality Analysis.



Throughout this review there are several references to on-going and new initiatives to ensure ARL stays on the forefront of technological change and has the capability and agility to adjust and adapt to new ideas and breakthroughs on a real-time basis. These initiatives range from outreach and collaborations, to improvements to our facilities and equipment and high-risk/high-payoff seed projects in emerging, exploratory and expanding fields. Regardless of the initiative, the concept is the same – to keep ARL a vibrant, world-class research facility that can attract and retain outstanding scientific and engineering professionals. This is a never-ending pursuit that has no finish line, and no end to challenges, but as you will see in these pages, it is one we are winning.

This review begins with an introduction that includes our organization, personnel, infrastructure initiatives, awards and other recognition earned by ARL and its personnel, and support to current operations. The remainder of the publication is structured around the nine TFAs identified above. Again, the accomplishments presented here, while only a small sample of our efforts over the past year, are representative of the skill, dedication, and teamwork of our in-house staff and our partners in academia and industry.

Many Minds, Many Capabilities, Single Focus on the Soldier.

Overview



The U.S. Army Research Laboratory (ARL) of the U.S. Army Research, Development and Engineering Command (RDECOM) is the Army's corporate, or central, laboratory. Its diverse assortment of unique facilities and dedicated workforce of government and private sector partners make up the largest source of world-class integrated research and analysis in the Army.

By combining its in-house technical expertise with those from academic and industry partners, ARL is able to maximize each dollar invested to provide the best technologies for our Soldiers. ARL's program consists of basic and applied research (6.1 and 6.2) and survivability/lethality and human factors analysis (6.6). ARL also applies the extensive research and analysis tools developed in its direct mission program to support ongoing development and acquisition programs in the Army Research, Development, and Engineering Centers (RDECs), Program Executive Offices (PEOs)/Program Manager (PM) Offices, and Industry. ARL has consistently provided the enabling technologies in many of the Army's most important weapons systems.

Technology and analysis products are moved into RDECOM RDECs and to other Army, Department of Defense (DoD), government, and industry customers. The Army relies on ARL to provide the critical links between the scientific and military communities. The Laboratory must marshal internal and external science and technology assets to fulfill the requirements defined by or requested by the Soldier. Equally important, the Laboratory must assist the Army user in understanding the implications of technology on doctrine and in defining future needs and opportunities.

Mission



The mission of ARL is to "Provide the underpinning science, technology, and analysis that enable full-spectrum operations." Within ARL we have teams working in partnership with the RDECs, Rapid Equip Force (REF), Joint Improvised Explosive Device Defeat Organization (JIEDDO), and others on the following tasks: current operational technical challenges facing Soldiers in Iraq (OIF – Operation Iraqi Freedom) and Afghanistan (OEF – Operation Enduring Freedom), maturing and transitioning technologies in the two to five-year timeframe for existing systems, and generating scientific discoveries that will provide the foundation for Soldier capabilities 15-20 years in the future.

Our mission statement is simple to state, but complex and difficult to execute considering the dissimilarity in urgencies of need across our customer base. Our team members understand our mission and they are proud of the contributions they are making for our Soldiers. Providing new or enhanced capabilities for our Soldiers dictates our research program content, recruitment and development of human capital, investments in technical infrastructure, and refinement of our business processes.

Vision

ARL's vision is articulated in a theme statement with three integral elements. It is used to guide organizational alignment and provide a comprehensive framework for critical review of our investments in research programs, technical infrastructure, and workforce development. Performance standards at all levels reflect the focus of each employee on achieving the goals.

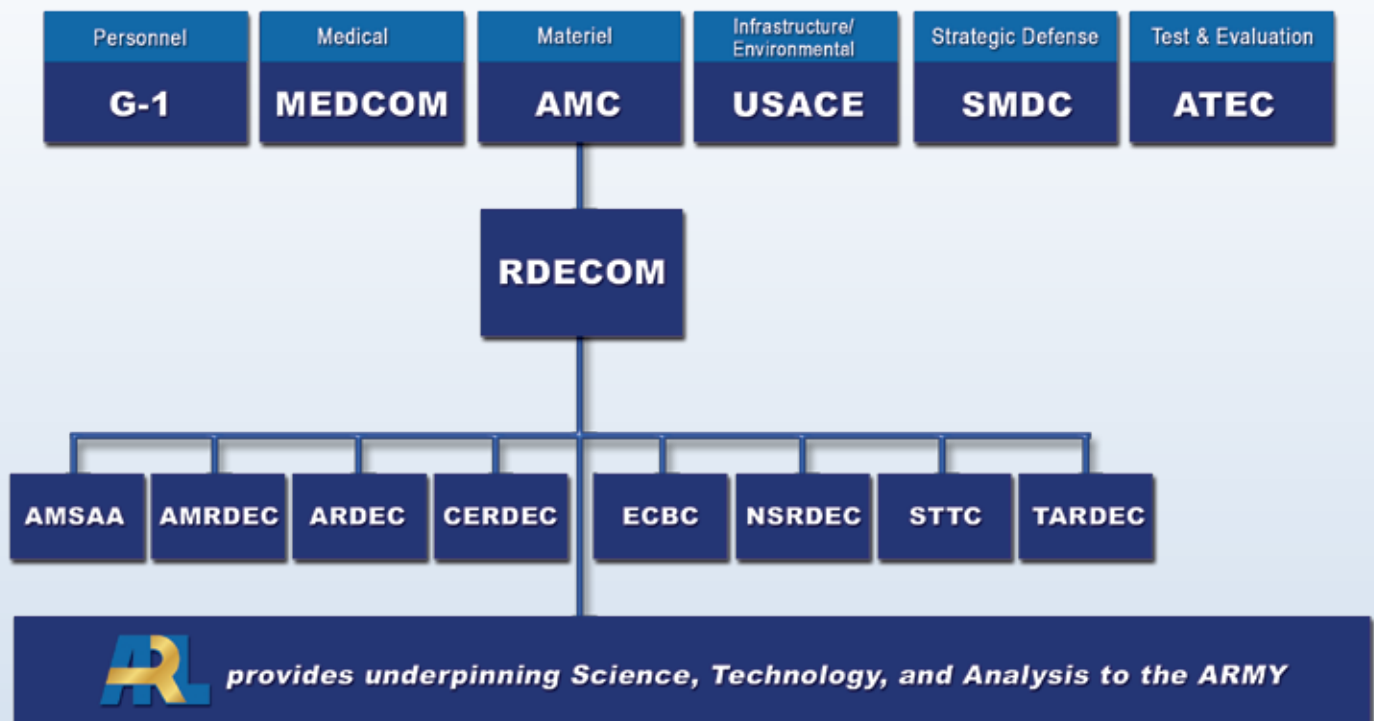
The theme statement is: *Many Minds, Many Capabilities, Single Focus on the Soldier.*

The elements are:

- Acknowledged for scientific, technical, and analytic excellence;
- Recognized as the bridge between the nation's S&T communities and the Army;
- Leader in providing innovative solutions for the current and future Army.

Organizational Role

ARL is a subordinate element of the U.S. Army Research, Development and Engineering Command. We are a \$1.8 billion a year organization that provides the underpinning basic and applied research for the Army and supports the efforts of a wide variety of customers ranging from the Army's Life Cycle management Commands, our sister Services, DoD and other government agencies. Of the total revenue received in FY09, over 52 percent (\$944 million) came from ARL customers. Through its partnerships with academia and industry, ARL also leverages several billion additional dollars of research.



Teams within ARL are working in partnership with the Research, Development and Engineering Centers, the Rapid Equip Force, the Joint Improvised Explosive Device Defeat Organization, PEOs/PMs, and others to solve current operational technical challenges facing Soldiers in Iraq and Afghanistan, to mature and transition technologies for existing and developmental systems, and to generate the scientific discoveries that will provide the foundation for Soldier capabilities 15-20 years in the future.

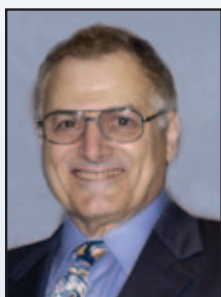
ARL Technical Assessment Board

Since 1996, ARL has had a relationship with the National Research Council (NRC), of the National Academy of Sciences, whose mission is to improve government decision making and public policy, increase public education and understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health.

The work of the NRC is made possible by 6,000 of the world's top scientists, engineers, and other professionals who volunteer their time without compensation to serve on committees and participate in activities.

As part of this relationship with the NRC, ARL has in place a Technical Assessment Board. The charge of this Board is to provide biennial assessments of the scientific and technical quality of ARL. These assessments include the development of findings and recommendations related to the quality of ARL's research, development, and analysis programs. We use their input to ensure our work is at the leading edge.

Board Members



Lyle H. Schwartz

Director (retired)
Air Force Office of Scientific Research



Peter M. Kogge

Professor of Computer Science
and Engineering
Concurrent Professor of
Electrical Engineering
University of Notre Dame



Donald M. Chiarulli

Professor of Computer Science and
Computer Engineering
Department of Computer Science
University of Pittsburgh



Kenneth Reifsnider

Director, Future Fuels University
Initiative and Professor of
Mechanical Engineering
Director, Solid Oxide Fuel Cell
Program
University of South Carolina



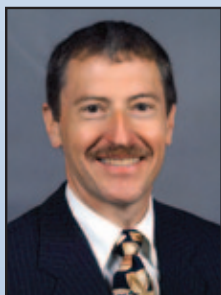
MarjorieAnn EricksonKirk

President
Phoenix Engineering Associates, Inc.



Jeremy M. Wolfe

Professor of Ophthalmology
Visual Attention Laboratory
Harvard Medical School
Brigham and Women's Hospital



George T. Gray, III

Laboratory Fellow
Fellow of ASM International
Fellow - American Physical Society
Los Alamos National Laboratory, FASM

Key Facilities

ARL has six primary sites: Adelphi, Md.; Aberdeen Proving Ground, Md.; White Sands Missile Range, N.M.; Raleigh-Durham, N.C.; Langley, Va.; and Glenn, Ohio. Unique facilities at our primary sites provide our scientists and engineers access to world-class research centers.

Electromagnetic Vulnerability Assessment Facility



The new facility addresses the complete electromagnetic threat being encountered in theater and anticipated for the Future Force.

Novel Energetics Research Facility



This facility contains a processing complex with energetics processing and manufacturing labs, an explosives casting lab, and it also has explosives x-ray capability.

Shooting Simulator



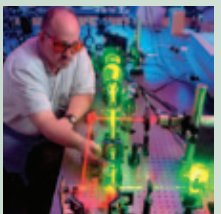
An indoor small arms shooting performance simulator with a high-speed weapon tracking system that provides real-time continuous weapon aim point data.

Robotics Research Facility



This 13-acre course is used for unmanned vehicles and indirect driving studies. Driving paths include straightaways, slaloms, tight turns, and straight and broad paths in which obstacles such as logs and rocks must be avoided.

Laser Optics Testbed



This laboratory is equipped to support sophisticated investigations in adaptive and nonlinear optics, advanced imaging and image processing, and laser communications for ground-to-ground applications.

Pulse Power Facility



This facility provides a full-scale test bed for development, evaluation and demonstration of continuous power components.

Mobility/Portability Research Facility



The Army standard for measuring the effects of various equipment configurations and loads on Soldier mobility and physiological performance.



Vertical Impulse Measurement Facility

Facility for measuring accurately the combined debris and blast impulse produced in landmine detonations. Data are used to validate models and develop technologies for improved survivability of future lightweight tactical and combat vehicles.

Tactical Environment Simulation Facility



This facility integrates, under one roof, the Omni-Directional Treadmill (ODT) into virtual visual and auditory environments to enable laboratory controlled investigations.

Rodman Materials Research Laboratory



The Rodman has nearly 300,000 sq. ft. of laboratories that enable the pursuit of disruptive and challenging research and characterization in advanced materials technologies for potential applications in Army weapon systems.

Transonic Experimental Research Facility



Among other things, this facility evaluates aerodynamics and fluid dynamics of projectiles, smart munitions systems, and sub-munitions dispense systems.

Zahl Physical Sciences Laboratory



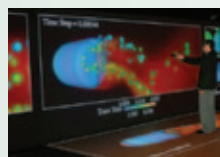
The Zahl's cornerstone is its clean room. The lab enables basic and applied research and analysis in nanobiotechnologies; flexible electronics; advanced specialty electronics material growth; nonlinear material research and characterization; and power electronics.

Airbase Experimental Facility #6



This modern, centralized complex provides analysts, program managers, and decision makers with experimental data that addresses the SLV of air and ground combat systems.

MSRC & Scientific Visualization Facility



This facility features state-of-the-art scalable parallel architectures and large vector-parallel systems supporting both classified/unclassified missions throughout the DoD's RDT&E community.

Clean Rooms



This facility features a 10,000 sq. ft. class 100 and 4,200 sq. ft. class 10 clean-room device processing facility.

The Army Research Laboratory is the RDECOM lead agency for planning and executing research opportunities with academia. ARL has a number of complementary mechanisms for academic partnering, ranging from single investigator grants with individual university faculty, to large centers with groups and consortia, to direct collaborations between university research personnel and ARL in-house scientists, engineers and analysts.

In addition to these in-house facilities, ARL is actively engaged in funding research with over 250 universities and colleges located in all 50 states.



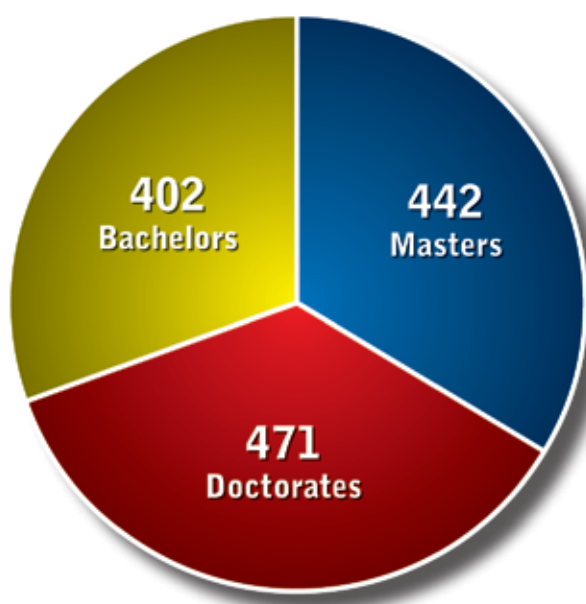
The ARL Team

ARL accomplishes its mission through the work of a highly educated and trained technical and support staff of 1,988 individuals. Of the 1,988 employees, 1,315 are classified as Scientific and Engineering (S&E), 913 of whom hold advanced degrees.

An organization is only as strong as the summation of the skills, expertise, and dedication of its workforce. ARL understands that our intellectual capital is our most critical resource. All research staffing decisions include a critical evaluation regarding generation or continuance of an internal capability vice reliance on external research partners and collaborators. Our goal continues to be a preeminent, multi-disciplinary, adaptive, and learning ARL team capable of meeting the challenges associated with the Soldier's technology requirements.

ARL recruits for and fills positions with the highest caliber applicants. Our interaction with ARL's network of research partners provides the opportunity to interact with graduate students and post-docs with the required expertise from which to recruit and our Personnel Demonstration Project allows starting pay to be negotiated in a competitive range.

1,315 Scientific & Engineering Employees



1,571 Technical Staff

282	Electrical/Electronics Engineers
205	Physicists/Physical Scientists
186	Mechanical Engineers
92	General/Industrial Engineers
36	Aerospace Engineers
69	Materials Engineers/Metallurgists
56	Engineering Psychologists
89	Chemical Engineers/Chemists
11	Biologists
7	Neuroscientists
54	Operations Research Analysts
154	Computer Scientists/Engineers
41	Mathematicians/Statisticians
18	Meteorologists
5	Ceramic Engineers
10	Other E&S
256	E&S Technicians

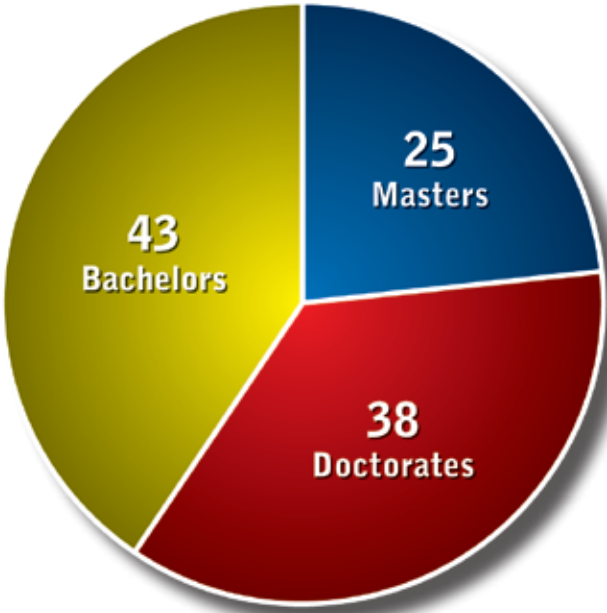
ARL's technical staff must be highly skilled to accomplish our mission and our leadership stresses the importance of advanced technical degrees. In FY09, the ARL scientific and engineering staff was composed of 471 (36 percent) doctorates, 442 (34 percent) Master of Science degrees, and 402 (30 percent) Bachelor of Science degrees.

Key performance indicators for quality of the research staff include metrics reflecting the attitudes and technical opinions of the external research community essential for achieving the first element of our vision. For FY09, ARL performed exceptionally in the number of presentations/proceedings (1,601), refereed journal articles (313), technical reports (514), books published (1), chapters of books written (16), patents awarded (34), and invited talks (42). The ARL staff holds 597 memberships in professional organizations and societies; in those organizations there are 66 ARL scientists and engineers who are Fellows, and 51 of our scientists and engineers hold prestigious posts.

The strength of ARL truly lies in its intellectual diversity. Through focused recruiting efforts, we attract scientists and engineers from a large number of academic institutions worldwide. As a result of these efforts, ARL hired 106 new scientists and engineers in FY09 including 38 with doctorates and 25 with Master of Science degrees, with 47 from Tier 1 schools. ARL strives for diversity of intellectual thought in its new hires and actively recruits from a wide range of schools.

**New Hires
Degrees Awarded by:**

Allegany College of Maryland	Salisbury University
Bowie State University	St. Mary's College
Cecil College	Stony Brook University
Cornell University	Towson University
Drexel University	University of Dayton
Duke University	University of Delaware
George Washington University	University of Florida
Goucher College	University of Maryland – Baltimore County
Howard University	University of Maryland – College Park
Jackson State University	University of Nevada, Las Vegas
Johns Hopkins University	University of North Carolina at Chapel Hill
Massachusetts Institute of Technology	University of Oregon
Montgomery College	University of Pennsylvania
North Carolina State University	University of Rochester
Oregon State University	University of Texas
Penn State University	University of Western Kentucky
Purdue University	University of Wisconsin
Rensselaer Polytechnic Institute	Utah State University
Rochester Institute of Technology	Virginia Tech
	West Virginia University



Outreach Initiatives

At ARL, we understand that science and technology have been and will remain the engines of economic growth and national security in the United States. In addition, we understand that excellence in discovery and innovation in science and engineering are the direct result of a well-educated workforce. It is a workforce that is being challenged by two trends: the global competition for science and engineering talent that impacts the pool of available scientists and engineers (S&Es) available in the United States; and the declining number of native-born S&E graduates entering the workforce. ARL is poised to intervene and improve the success in educating S&E students from all demographic groups, especially those that have been historically underrepresented in S&E careers.

With these national concerns and challenges in mind, ARL has made a corporate commitment to help develop the next generation of Army scientists and engineers by establishing an Outreach Program (OP) Office. The OP was expressly designed to address the projected shortfall of scientists and engineers among diverse populations of the 21st Century, to leverage technical capabilities of academia (including Historically Black Colleges and Universities/Minority Institutions (HBCU/MIs)) to fulfill ARL requirements, and to expand the involvement of HBCU/MIs in ongoing research at ARL. The objective of ARL's OP Office is to develop and execute programs that provide learning and teaching aids, incentives, and rewards for students and teachers while ensuring opportunities for socially and economically disadvantaged students.

Key programs include:

ARL Summer Student Symposium

eCybermission (the Science Fair for the Nation)

FIRST – For Inspiration and Recognition of Science and Technology

GEMS – Gains in the Education of Mathematics and Science

JSHS – Junior Science and Humanities Symposium

MWM – Materials World Modules

REAP – Research and Engineering Apprentice Program

SEAP – Science and Engineering Apprentice Program

SMART – Science, Mathematics And Research for Transformation

STARS – Science and Technology Academic Recognition System

UNITE – Uninitiates Introduction to Engineering

For more information, visit: www.arl.army.mil/outreach

Stanford Hosts Inaugural AHPCRC Undergraduate Summer Institute

The inaugural Army High Performance Computing Research Center (AHPCRC) Undergraduate Summer Institute in Computational Science and Engineering was held at Stanford University from June 22 to Aug. 14. Participants included 16 undergraduate students from five universities. A group of Stanford professors, research associates, postdocs, and graduate students served as instructors and mentors.

Our relationship with the AHPCRC allows us access to advanced computational science and engineering which are critical to Army research challenges.

The Undergraduate Summer Institute represents a key part of the AHPCRC mission – to foster the education of the next generation of scientists and engineers, including those from racially and economically disadvantaged backgrounds, in the fundamental theories and best practices of simulation-based engineering sciences and high performance computing.

Undergraduate students spent their time learning computational science and engineering concepts from experts in these fields, drawn from both the Stanford faculty and computer scientists from NVIDIA Corporation and AHPCRC consortium member High Performance Technologies, Inc.

Additionally, the students were afforded an opportunity to work directly with AHPCRC researchers. They simulated aircraft wings, submarines, bulletproof fabrics and advanced nanoscale materials. Students also helped design the underlying computer algorithms and architectures that made the other projects possible.

The students also learned about numerical methods used in computational science and engineering, and they received an introduction to computational engineering methods and modeling, meshing computational domains, ordinary and partial differential equations, and optimization problems. They also learned to program in several commonly used computer languages and systems, including C, MATLAB, MPI, and specialized programming for GPU processors.



Stacey Oriaifo, undergrad, Morgan State University (left), Highly Anisotropic Iron in Fusion and Nuclear Power Plants, mentors: Sylvie Aubrey (right, research associate), Wei Cai (faculty).



Kalesanmi (Sanmi) Kalesanwo (right), undergrad, Morgan State University, Higher Order Scattering on Submerged Objects, mentors: Paolo Massimi (left, postdoc), Charbel Farhat.



Student presentation day, Aug. 14, 2009. Army Research Laboratory representatives, left to right: Vallen L. Emery Jr., Ph.D. (Minority Outreach Program Manager), Lt. Col. Fredrick C. Ludden (Military Deputy, Computational and Information Directorate), Dr. Raju Namburu (AHPCRC Cooperative Agreement Manager).

Partnerships and Collaborations

ARL is partnering and collaborating with academia, industry, and other government organizations through a variety of continuing and new innovative programs. Our intent is to maximize the use of our limited research dollars by leveraging the resource investments of our partners using a variety of approaches ranging from single investigator grants with individual university faculty, to large centers with groups and consortia, to direct collaborations between university research personnel and ARL in-house scientists, engineers and analysts.

Collaborative Technology Alliances

**Micro
Autonomous
Systems &
Technology**

Robotics

Neuroergonomics

**Network
Science**

University Affiliated Research Centers

Biotechnology

ICB

Biologically-derived:
■ Sensors
■ Electronics
■ Information Processing

Nanotechnology

ISN

■ Protection
■ Performance
Enhancement
■ Injury Intervention
and Cure

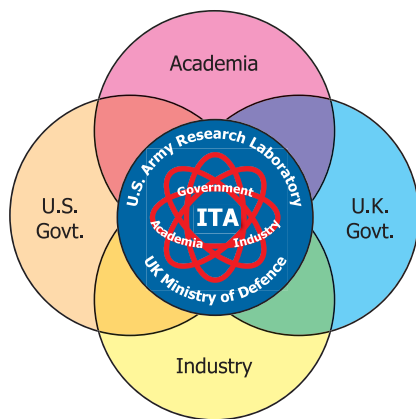
**Electromechanics &
Hypervelocity Physics**

IAT

■ EM Launch
■ Pulsed Power
■ Electric Armaments

Partnership Programs

Single Investigator Program
Multidisciplinary University Research Initiative Program
Collaborative Technology Alliances
Centers of Excellence
HBCU/MI ARO Core Grants
Battlefield Capability Enhancement Centers of Excellence
SBIR/STTR
University Affiliated Research Centers
Defense Experimental Program to Stimulate Competitive Research
Short Term Innovative Research



International Technology Alliance

Centers of Excellence

High Performance Computing

Stanford University
New Mexico State University
Morgan State University
University of Texas, El Paso
High Performance Tech, Inc.
NASA - Ames

Flexible Displays

Arizona State University

Materials

University of Delaware
Johns Hopkins University
Rutgers University
Drexel University
Virginia Tech

Communications and Networks CTA

Benefiting the Soldiers of Tomorrow



Dr. John Gowens

Director for
Computational
and Information
Sciences

As the Communications and Networks Collaborative Technology Alliance (CTA) comes to a close, now is a chance to reflect on its work and to mention a few of its successes.

The CTA was a partnership between Army Laboratories and Centers, private industry, and academia with an objective of developing the underpinnings for dynamically self-configuring wireless network technologies that enable secure, scalable, energy-efficient, and reliable communications for command on-the-move.

These collaborative efforts sought to enable large, heterogeneous, wireless communications networks that operate while on-the-move with a highly mobile network infrastructure; under severe bandwidth, energy, and processing constraints; and while providing secure, jam-resistant communications in noisy hostile battlefield environments.

To achieve these goals, the CTA research was organized into three technical areas: 1) Survivable Wireless Mobile Networks, 2) Signal Processing for Secure Communications and Networks, and 3) Tactical Information Protection. In FY09, the CTA completed its research mission that began eight years earlier.

During its lifecycle, the CTA generated more than 30 technology transitions and some specific examples of CTA developed technology transitions follow:

- The Multi-Objective Network Optimization and Assessment Tool (MONOPATI) which provides an automated generation of optimal network hierarchies that allow a large force to operate immediately upon arrival in theater was transitioned to Communications-Electronics Research, Development, and Engineering Center's (CERDEC's) Mobile Ad Hoc Network (MANET) Design program.
- The Distributed Survivable Resource Control-tactical (DSRC-T) framework improves core networking performance by controlling/managing network resources efficiently was transitioned to CERDEC's Proactive Integrated Link Selection for Network Robustness (PILSNER) program.
- The Intrusion Detection for MANET's technologies produced results in organizing, coordinating and controlling distributed intrusion detection components using a dynamic hierarchy were transitioned to CERDEC's Tactical Wireless Network Assurance program.

The CTA truly was a success for ARL and its partners. The collaborative efforts of all involved produced results that were transitioned to CERDEC and will benefit the Soldiers of tomorrow.

Partnerships and Collaborations

INTERNATIONAL COLLABORATIONS

International Collaborations Bring About Exchanges and Agreements

International cooperation has the potential to significantly improve interoperability for coalition warfare, to leverage scarce program resources, and to obtain the most advanced, state-of-the-art technology from the global technology and industrial base.

The fundamental objectives of cooperation in defense research, development, testing, evaluation, and acquisition are:

- **Operational** – to increase military effectiveness through interoperability and partnership with allies and coalition partners.
- **Economic** – to reduce weapons acquisition cost by sharing costs and economies of scale, or avoiding duplication of development efforts with our allies and friends.
- **Technical** – to access the best defense technology worldwide, and help minimize the capabilities gap with allies and coalition partners.
- **Political** – strengthen alliances and relationships with other friendly countries.
- **Industrial** – bolster domestic and allied defense industrial bases.



ARL recognizes that cooperation programs offer unique opportunities for promoting U.S. security and technology advancement. To meet these objectives, ARL has collaborated with traditional foreign allies and reached out to new foreign partners.

In FY 2009, ARL activity in international collaborations was most active in the technology areas of survivability, lethality, and network sciences. We initiated collaborative efforts with Germany, the United Kingdom, and Australia in the areas of materials and warheads and re-energized materials data exchanges with Japan, Korea, and France. The Network and Information Sciences International Technology Alliance with the United Kingdom completed its third full year and is increasingly recognized as a model for international collaboration involving industry, academia, and government partnership.

To help foster personal relationships and solidify future collaborations between nations, ARL is an active participant in the Engineer and Scientist Exchange Program (ESEP) and also promotes international collaboration by hosting and participating in senior level discussions. In FY09 ARL participated in senior level visits from Chilean, Israeli, United Kingdom, French, Singapore, Australian, Canadian, and Italian delegations.



Top and bottom photos: ARL researchers discuss their cutting-edge research with Chilean officers during a visit to ARL in 2009.

CENTERS OF EXCELLENCE

ARL Patented Technologies Producing “Green” Results

Low-cost composite materials are used in a variety of military systems across the Services. Some of these include hulls of small boats, replacement hoods for HMMV's (humvees), helicopter and plane parts and in new Navy DDX and DDG ships. As a result of the high performance and low weight of composite materials, it is very likely that the Services will be using more and more composite materials in the future.

Until now the monomer styrene has been used as a diluent in resins for molding, shaping and extruding composite materials. Unfortunately, styrene is classified as a hazardous air pollutant (HAP) and volatile organic compound (VOC) and has recently been considered a suspected carcinogen. As a result, styrene is strictly regulated by the U.S. Environmental Protection Agency.

To address this problem, Drexel University and the Army Research Laboratory developed and patented three technologies that enable the manufacture of resins for composites and for resin repairs that reduce the use of styrene and consequent VOC and HAP emissions.

The first technology employs fatty acid monomers as a substitute for styrene in composite resins like vinyl ester, without compromising key performance characteristics. The second technology substitutes fatty acid monomers for styrene in unsaturated polyester and vinyl ester repair resins, while maintaining repair performance. The third technology enables reduction of styrene content in vinyl ester resins while increasing fracture toughness by combining vinyl ester monomers of different molecular weights.

As ARL and Drexel jointly invented the technologies under a Cooperative Agreement, becoming joint owners of the intellectual property, the parties agreed to enter into a Joint Ownership Agreement (JOA) in order to establish the opportunity to exclusively license the technologies. The government retains the right to practice the technology for government purposes. ARL and Drexel agreed that Drexel would be the licensing party which allowed greater flexibility in licensing the technologies.

The joint development of this “green” technology represents over seven years of technical collaboration. Additionally, the collaborative efforts of ARL's and Drexel's Legal and Technology Transfer Offices provided for a seamless transfer of the technologies to the commercial sector.

Flexible Display Center

Spearheading the Next Revolution in Information Displays



**Dr. John
Pellegrino**

Director for
Sensors and
Electron Devices

The objective of the U.S. Army's Flexible Display Center (FDC) is to develop technologies and manufacturing processes that will enable the realization of lightweight, rugged, ultra-low power flexible displays and electronics.

Flexible displays are creating novel applications through the FDC partnership; such as wearable and conformal displays for Soldier situational awareness and ultra-low power, sunlight readable displays for robotic asset control. Other novel

applications include electronic manuals and wearable maintenance aids for logistics, conformal, light weight displays for vehicles and ultimately roll-up displays.

The FDC partnership model has been a critical attribute towards achieving the Army's program goals. The FDC has 27 industry partners that actively contribute company resources to development projects within the Center's World Class GEN II flexible display pilot-line facility.

In addition, the industry partners contribute to system demonstrations that are transitioning to the Army through several transition partnership agreements including; two Technology Transition Agreements (TTAs); PM Common Controller, ARL, and Tank-Automotive Research, Development and Engineering Center and the Program Executive Office-Soldier, ARL and Natick Soldier Research, Development and Engineering Center.

The FDC roadmap is coordinated through the Army's Research, Development and Engineering Centers (RDECs) Flexible Display Working Group. The working group includes representatives from each of the RDECs, ARL, PEO Soldier, PM Common Controller, and SOCOM. FDC is generating Intellectual Property rights for manufacturing flexible displays.

Also, the FDC is developing key strategic partnership for advanced flexible electronics and sensors to compliment a growing intellectual property (IP) applications portfolio. The IP is governed through the unique industry Participation Agreement and government rights.

Recognitions and Awards

ARL Garners Two Presidential Rank Awards



Dr. John Pellegrino, director of the Sensors and Electron Devices Directorate, and Dr. Kwong-Kit Choi, senior research scientist for physical sciences in SEDD and an ARL Fellow, both were selected to receive a 2009 Presidential Rank Award. Each year, the President recognizes and celebrates a small group of career senior executives and senior career employees with the Presidential Rank Award. Recipients of this prestigious award are strong leaders, professionals, and scientists who achieve results and consistently demonstrate strength, integrity, industry and a relentless commitment to excellence in public service. Pellegrino

was selected as a Meritorious Executive and Choi was selected as a Distinguished Senior Professional.

Black Engineer of the Year - Deans Award



Dr. Val Emery, ARL's outreach program manager, received the prestigious U.S. Army's Superior Civilian Service Award and the Black Engineers of the Year Deans Award for his extensive work with historically black colleges and universities. Through his extensive outreach work from October 2003 through December 2008, Emery facilitated the development and sustainment of many critical university relationships in an effort to engage top technical talent in service of Soldiers. For more than two decades, the BEYA conference has showcased the outstanding contributions of blacks in the fields of science, engineering, technology and math.

Louis Dellamonica Award for Outstanding AMC Personnel of the Year



Dr. Douglas Kiserow of the Army Research Office was named a recipient of the 2009 Dellamonica Award for Outstanding U.S. Army Materiel Command (AMC) Personnel of the Year. The award, named after Louis Dellamonica, a former general engineer with AMC's Hawthorne Army Depot, is given to ten employees each year who improve AMC's mission, motivate other employees, and are viewed in high regard by their colleagues. Kiserow was honored at Headquarters AMC on May 1 at Fort Belvoir.

IEEE-USA Harry Diamond Award

Dr. Dwight Woolard – ARO

University of Maryland Invention of the Year Award

- Dr. Paul Yu – CISD
- Dr. Brian Sadler – CISD

2009 Hispanic Engineer National Achievement Award for Outstanding Technical Achievement

Dr. Joseph Montoya – SLAD

2009 Hispanic Engineer National Achievement Award for Information Technology

Dr. Juan Pelaez – CISD

Standards Medallion by the IEEE-Standards Association

John Cole – CISD

NASA Exceptional Technology Achievement Medal

Dr. Dongming Zhu – VTD

Research and Development Achievement Awards

Sensors and Electron Devices Directorate:

- Dr. Grace Metcalfe
- Dr. Paul Shen
- Dr. Michael Wraback
- Christian Reiff
- Michael Scanlon
- Dr. Tung-Duong Tran-Luu
- Hao Vu
- David Gonski
- Eugene Zakar
- Brian J. Mary
- Dr. John Noble

Weapons and Materials Research Directorate:

- Dr. Adam Rawlett
- Dr. Joshua Orlicki
- Dr. Joseph Dougherty
- Dr. Jan Andzelm
- T. Gordon Brown
- Dr. Robert Hoffman
- Dr. Timothy Prichett
- Dr. Frank DeLucia, Jr.
- Dr. Jennifer Gottfried
- Dr. Chase Munson
- Dr. Andrzej Miziolek
- Dr. Michael Nusca
- Dr. Brian Scott
- Dr. James Newill
- Dr. Frank Fresconi
- Dr. Mark Ilg
- Ilmars Celmins
- Dr. James DeSpirito
- Dr. Jerome Tzeng
- Dr. Ryan Emerson
- Robert Kaste
- Dr. Gary Gilde
- Victor Champagne
- David Gray
- Paul Moy
- Dr. Shawn Walsh

Vehicle Technology Directorate:

- Dr. Mary Anne Fields

Army Research Office:

- Dr. Jennifer Becker

Computational and Information Directorate:

- Ronald Meyers
- Keith Deacon
- Dr. Yansen Wang
- Chatt Williamson

Human Research and Engineering Directorate:

- James Davis
- Dr. Kaleb McDowell

North Atlantic Treaty Organization's 2009 Research and Technology Organization Scientific Achievement Award

- Dr. Tien Pham – SEDD
- Nino Srour – SEDD

American Institute of Aeronautics and Astronautics Aerodynamics Award

- Dr. Jubaraj Sahu – WMRD

Defense Standardization Program Achievement Award

- WMRD – Cold Spray Manufacturing Process

Army's Greatest Inventions Program (CY08)

MRAP Armor Weight Reduction Spiral Program

Weapons and Materials Research Directorate:

- Dr. Scott Schoenfeld
- Thomas Havel
- Melissa Love
- Richard Mudd
- Dr. Jonathan Montgomery
- Dave Kleponis
- Valerie Hernandez
- Kirk Stoffel
- Dr. Patrick Baker
- Dr. Brian Scott

Survivability/Lethality Analysis Directorate:

- Paige Mergler
- Carolyn Stancoff
- Rebecca Young
- Anne Berry
- Randolph Coates
- Thomas Adkins

MRAP Expedient Armor Program (MEAP) - Collaboration with TARDEC

Survivability/Lethality Analysis Directorate:

- Paige Mergler
- Carolyn Stancoff
- Merrill Dougherty
- Rebecca Young
- Robert Storey
- John Abell

Weapons and Materials Research Directorate:

- Gary Boyce
- Robert Anderson
- Tom Havel
- Valerie Hernandez
- Dr. Robert Doney
- Dr. Jonathan Montgomery
- Mike Keele
- Dr. Scott Schoenfeld
- Jared Rochester
- Dave Kleponis
- Kirk Stoffel
- Melissa Love
- Steve Boyer
- Tom Barnhill
- Sarah Hug

Computational and Information Directorate:

- Dr. Hubert Meyer

Excellence in Federal Career Awards

Gold:

- Dr. Jennifer Gottfried – WMRD

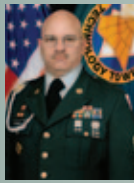
Silver:

- Karl Kappra – SEDD
- Dr. Parimal Patel – WMRD
- Mary Beth Hennemuth – SLAD
- David Hopkins – WMRD

Bronze:

- Mary Oliver – SLAD
- Gary Carhart – CISD
- Teresa Kines – Laboratory Operations
- Dr. Ralph P.I. Adler – WMRD (Retired)

Recognitions and Awards



Legion of Merit

Sgt. Maj. Steven Hornbach



Meritorious Service Medal

Lt. Col. Kevin Geisbert

Maj. Christopher Linz

Maj. Richard Moyers

Master Sgt. Ralph Brewer

Master Sgt. James Laverty

Sgt. 1st Class William Childs

Sgt. 1st Class Benjamin Davis



Army Commendation Medal

Maj. Richard Moyers

Staff Sgt. Collin Moore



Army Achievement Medal

Staff Sgt. Da Shawna Wingate



Distinguished Honor

Sgt. Maj. Steven Hornbach receives the Legion of Merit Award from ARL Director John Miller for exceptionally meritorious service during his 30-year career.

ARL Fellows



ARL Fellows: An Elite Group

The Fellows of the Army Research Laboratory play a vital role at the laboratory. Their overall mission is to achieve, promote and maintain technical excellence in science and engineering at ARL. The Fellows serve as advisors and consultants on technical matters to the ARL Director and the Directorate Directors.

The Fellows of the Army Research Laboratory are carefully chosen from the ARL community, itself a distinguished collection of some of the top scientific minds in our Nation. Only 1.5 percent of the scientist and engineer workforce at ARL can be Fellows. The selection criteria include an emphasis on nominating those researchers performing the very highest quality ongoing S&E work that also has an extremely high impact on Army needs, the mission, and their field of endeavor. The first ARL Fellows were elected in 1993. The Fellows endeavor to be representative of ARL as a whole. To this end, the ARL Fellows Charter provides procedures that assure a field of candidates drawn from the entire laboratory. There are currently 22 Fellows, 27 Fellows emeriti, and two Honorary Fellows.

Among some of their more important contributions have been evaluations of ARL technical awards, organizing special symposia, and chairing directorate promotion panels. In addition, each year the Fellows review proposals for the Director's Research Initiative, which is designed to support innovative and possibly high-risk research ideas that have the potential to significantly advance mission needs beyond conventional expectations.

Director's Research Initiatives

Pursuing High-risk, High-payoff Research

The Director's Research Initiative (DRI) program is designed to support innovative and possibly high-risk research ideas that have the potential to significantly advance mission needs beyond conventional expectations. The program encourages thinking "outside the box" in pursuing emerging or alternative technologies for which direct application to today's problems might not be possible, but which could have potential to address military needs in the long term.

The DRI program annually funds about 20 high-risk, high-payoff seed projects. The competition for the DRI funds is stiff and the selections are made upon the recommendation of the ARL Fellows. The DRI titled "Next Generation Highly Conducting Organic films using Novel Donor-Acceptor molecules for Opto-electronic applications" is one example of the kind of research being funded.

For this DRI, an ARL team of researchers developed novel conducting organic materials that will improve the device performance of several flexible electronics technologies for the Soldier at a lower total device operating power. Since power availability on the battlefield is one of the Army's great challenges, any increase of capability with the added benefit of reduced power requirements is a critical success for this effort.

ARL has transitioned the results of this work to the U.S. Army Flexible Display Center for evaluation in active matrix emissive flexible displays.

In addition, the designs developed are being investigated for photovoltaic applications in collaboration with a small business as part of Stimulus Act funding. The DRI research has led to a patent disclosure (written and to be filed), a journal publication, with additional publications in progress and two invited talks.

2009 Summer Student Symposium

The third annual Summer Student Research Symposium was held at Adelphi Laboratory Center Aug. 6, 2009. This year's program consisted of 99 undergraduate and graduate students who participated as interns in ARL research programs.

ARL interns participated in a wide range of research projects. The reports they generated were evaluated by directorate judging panels, and an undergraduate and graduate finalist from each directorate was selected to present at the symposium.

This year, 11 finalists presented their summer projects to an audience of peers, ARL staff, and a panel of judges comprised of ARL Fellows.

Winner in the undergraduate category: Tim Mackie, Messiah College - "Remediation of Waste Material" (SEDD)

Winner in the graduate category: Kyle Grew, University of Connecticut - "Transport Phenomena in Alkaline Anion Exchange Membrane Fuel Cells" (SEDD)



ARL Director John Miller stands with the 2009 ARL Summer Student Research Symposium presenters, their mentors and the ARL Fellows following the awards ceremony.

Infrastructure

To maintain our state-of-the-art status in facilities, ARL funds numerous infrastructure and equipment projects. Fiscal Year 2009 was a productive year in this regard. We funded fourteen projects totaling \$17 million under the ARL Director's Infrastructure Program. This is double the number of projects from the previous year. ARL directorates also maintained robust programs, investing a total of \$8.6 million.

As we did last year, ARL used the special Laboratory Revitalization Authority established by Congress in the Defense Authorization Act of FY08 for one of our new projects in FY09. This authority allows defense laboratories to expend up to \$2 million for minor construction. This project will refurbish a facility that supports rapid transitioning of critical technologies from ARL to theater operations in Iraq and Afghanistan and plays a crucial role in Intelligence, Surveillance, and Reconnaissance operations for both the United States and coalition forces. The facility, when completed, will provide a secure workspace for ARL researchers, supporting continuous data analysis and processing at the top-secret level, a capability which is vital to transitioning critical technologies in a timely fashion to the Warfighter. The facility will also provide a multi-level video teleconferencing capability able to support classified discussions up to the Top Secret level and provide space to support research relating to special-access programs.

Other projects funded by ARL this past year included upgrades to several major facilities at Aberdeen Proving Ground (APG) in support of our weapons and materials, vehicle technology, and survivability/lethality analysis directorates, and renovations and upgrades to facilities at our Adelphi location.

ARL has a number of on-going projects, funded both in previous years and in FY09 that are nearing completion. Two examples are the Bio/Nanotechnology Research Facility and the Open Environment for Auditory Research (Open EAR). Descriptions of both follow. In addition, ARL broke ground on a new Base Realignment and Closure (BRAC) funded facility at APG. That story is also presented here.

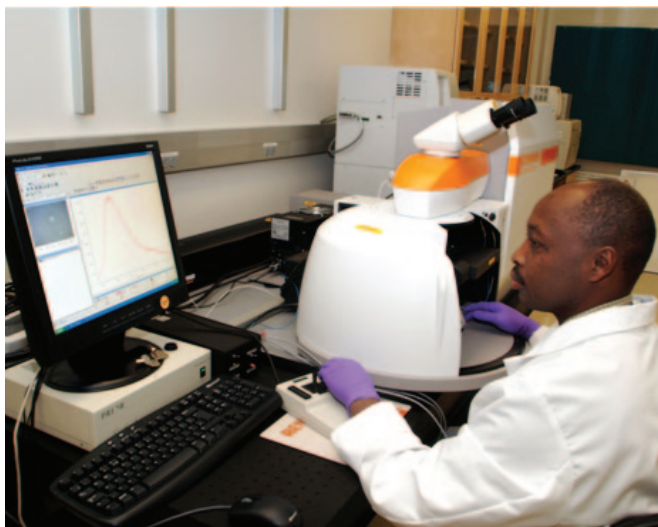
The Bio/Nanotechnology Research Facility

Final planned upgrades to the Bio/Nanotechnology Research Facility were approved in FY09. This facility allows ARL to leverage existing Microelectromechanical Systems (MEMS) and semiconductor fabrication capabilities to establish a unique combination of capabilities under one roof: Biotechnology, Nanotechnology, MEMS, and Semiconductor Device Fabrication. The facility takes advantage of the unprecedented advances in solid-state systems through the investigation of biological systems for novel applications (e.g., microbial fuel cells) and studies of the biological/electronic interface (e.g., for bio-responsive sensor platforms). Bio-mimetic approaches to nanoscale electronic circuit architectures have the potential to enable extremely high density electronic signal processing in a low power, thermally-managed configuration.



Dr. Dimitra Stratis-Cullum has access to state-of-the-art equipment at ARL's Bio/Nanotechnology Research Facility.

The facilities operate in open format that will allow interaction with research throughout the organization. This format will encourage biologically and nanotechnology inspired ideas and opportunities that span the organization as a whole and support work we perform for the Defense Research Advanced Programs Agency; the Defense Threat Reduction Agency; the Joint Program Executive Office for Chemical and Biological Defense; the Edgewood Chemical and Biological Center; and the U.S. Army Medical Command.



Dr. Troy Alexander conducts research at ARL's Bio/Nanotechnology Research Facility.

Open Environment for Auditory Research (EAR)

An important factor to be considered in interpreting results of any scientific study conducted in a simulated auditory environment is the degree to which this environment approximates the listening condition existing in real outdoor environments. Field studies designed to verify the data obtained in simulated environments are very expensive and they still have a drawback of being conducted in a different place, at a different time, and – usually – by different researchers and by different participants. To address this, we made improvements to ARL's world-class EAR facility to permit immediate comparison of a simulated auditory environment with the listening conditions existing in real outdoor environments. Two enhancements to the facility were made to convert the EAR into the Open EAR:



An interior look at ARL's world-class Environment for Auditory Research facility located at Aberdeen Proving Ground, Md.

First, an adaptive loudspeaker wall in the Distance Hall making the Distance Hall a space of unlimited length. This addition permits simulation of sound source movements from infinity to close proximity. Second, an outdoor expansion to the EAR to allow the same listener to switch from participation in laboratory experiments to a complementary field experiment or back to the laboratory experiment in a matter of a few minutes.

Infrastructure

New ARL Facility at APG

ARL hosted a groundbreaking ceremony Sept. 3, 2009 for its Vehicle Technology Directorate laboratory for specialized research, development, test and evaluation to be constructed at Aberdeen Proving Ground.

The U.S. Army Corps of Engineers, Baltimore District, initially awarded a \$14.8 million contract in June to Walbridge-Aldinger Construction Company of Detroit to build the 35,930-square foot building that will house VTD's Mechanics and Propulsion divisions relocating from NASA sites in Virginia and Ohio. The move was scheduled in the 2005 Base Realignment and Closure (BRAC) legislation and is expected to consolidate and streamline VTD, which already has elements at APG.

With a mission of producing mobility-related science and technologies, the directorate already has excellent scientists and engineers, and the U.S. Army Corps of Engineers is providing the facilities needed to do their jobs, said Dr. Mark Nixon, VTD director.

The fully-functional laboratory, including specialized equipment, is expected to cost about \$35 million when it's finished and will enable the directorate to conduct innovative in-house research in robotics, mechanics, propulsion and vehicle modeling as well as simulation, he added.

The building is expected to be completed by April 2011 and will include advanced capabilities to research aeromechanics and structures, mechanical systems and propulsion materials, among other areas.



The U.S. Army Research Laboratory broke ground on its new Vehicle Technology Directorate facility Sept. 3 at Aberdeen Proving Ground. From left, Gary Martin, executive deputy to the commander of the U.S. Army Research, Development and Engineering Command; John Miller, director of ARL; Dr. Mark Nixon, director of the VTD; Col. Orlando Ortiz, APG garrison and deputy installation and garrison commander; and Col. Peter DeLuca, commander and division engineer of the North Atlantic Division, U.S. Army Corps of Engineers.

A Unique Opportunity to Enhance Mobility

Consolidation at APG Brings Synergy



Dr. Mark Nixon

Director for
Vehicle Technology

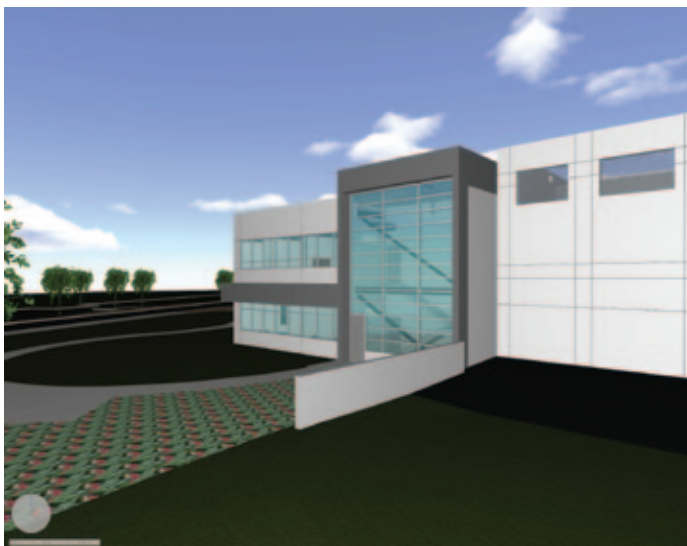
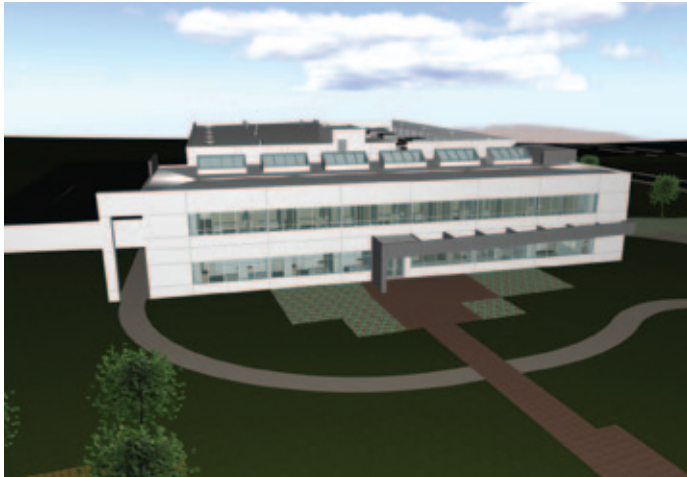
ARL's Vehicle Technology Directorate (VTD) is undergoing major changes as it responds to BRAC 2005. The BRAC precipitated consolidation of VTD personnel at Aberdeen Proving Ground (APG), Md., and construction of new offices and laboratory facilities are underway as of September 2009. The Robotics Program Office and Unmanned Vehicles Technologies Division, once part of the

Weapons and Materials Research Directorate, were realigned to VTD and will form the Autonomous Systems Division. The Mechanics Division will relocate from Hampton, Va. where it shares facilities with the NASA Langley Research Center, and the Propulsion Division will relocate from Cleveland, Ohio where it shares facilities with NASA Glenn Research Center.

The collaboration with NASA began in 1969 when the Army Materiel Command and NASA signed an agreement to collaborate on joint research in aeronautical technology. The two divisions at the NASA sites, which were part of the Aviation Research and Development Command, joined with the Structures Division of the Materials Technology Laboratory in Watertown, Mass. to form the Vehicle Technology Directorate when ARL formed in 1992. Field elements of five and six personnel will remain at the two NASA sites to continue the synergistic relationship with NASA utilizing unique facilities that are too costly to duplicate elsewhere.

VTD conducts basic and applied research to enhance Army mobility and logistics through vehicle platforms that are lighter in weight with increased performance and autonomy, while becoming more fuel-efficient, deployable, reliable, durable, and cost-effective.

The new facility at APG will bring VTD researchers in robotics, mechanics, propulsion and vehicle modeling and simulation together under one roof for the first time in its history.



Technology Planning Workshop

The U.S. Army Research Laboratory (ARL) hosted the U.S. Army Research Development and Engineering Center's (RDECOM) first Technology Planning Workshop (TPW) April 20-22, 2009 at the Adelphi Laboratory Center (ALC) in Adelphi, Maryland.

The purpose of the three-day workshop was to create a forum to communicate RDECOM's technical program and receive programmatic input and feedback from its partners to ensure its program is synchronized with their requirements.

Much of RDECOM's programs are executed in collaboration with external partners from industry, universities and other government agencies. The workshop provided a single forum for its partners and stakeholders to hear the command's proposed program plan and provide their needs, objectives and feedback that will ultimately shape the RDECOM program.

The workshop consisted of plenary sessions that included technology and system integration presentations, and technology and analysis exhibits and breakout sessions highlighting research, analysis and system integration objectives and activities.

Five Senior Non-Commissioned Officers (NCOs) addressed specific issues or problems that were encountered in their respective theaters of operation. These NCOs had all recently redeployed from theater within the last 15 months.

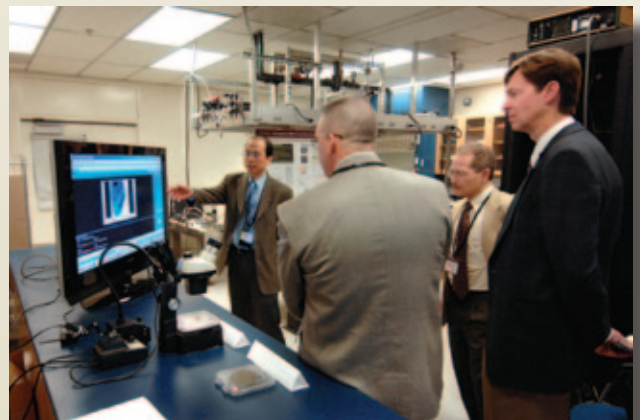
The topics of discussion were:

1. Individual Warfighter Equipment
2. Vehicle Protection and IED Defeat, (Armor, Bar Armor, MEAP and Reactive Armor),
3. Soldier Power (Batteries) and Vehicle Power
4. Communication / Electronic Equipment Detection and Surveillance Equipment
5. Robotic and UAV





An Interactive Workshop



Strategic Research Initiatives

The U.S. Army has evolved into a high-technology fighting force, relying on cutting-edge research and analysis to maintain its dominance. The research ARL performs to sustain such a force is inherently long-term in nature and may require 10-20 years of research and development before delivering innovative capabilities to our Warfighters. We have selected seven high-payoff Strategic Research Initiatives (SRIs) depicted below that can expand existing or establish new core competencies in support of our Technology Focus Areas.

The ARL Director's Strategic Initiatives (DSIs) are two-year funded efforts (\$500,000/year) for emerging (revolutionary) research areas in support of SRIs to potentially expand or establish new Core Competencies. DSIs support higher risk research that is collaborative, multi-disciplinary/multi-directorate. These initiatives present the opportunity to attract new researchers and develop new infrastructure and have long-term potential to deliver unprecedented capabilities for the Soldier.

						
						
Materials	Neuroscience	Network Science	Computational Sciences	Electronics	Energy Science	Autonomous Systems Technology
Multi-Scale Multi-Functionality Nano/Bio	Cognitive Performance Neuro-Cognitive Measurement Neuroergonomic System Designs	Cognitive/Information – Decision Making Communications Battlespace Information Processing System of System Analysis	Commodity Computing Scalable Algorithms Quantum Computing Multiscale Chemistry, Physics, & Mechanics M&S Comprehensive Human Modeling	Heterogeneous Devices Nano Quantum and Molecular Flexible Bio-Inspired	Nano to Micro Generators & Convertors Energy Harvesting & Scavenging Novel Energy Storage Bio	Autonomous Tactical Navigation & Manipulation Scalable Autonomy Intelligent Behavior Cognitive Robotics

In FY09 ARL funded nine DSIs in the areas of Bioscience, Neuroscience, Network Science of Decision Making, Nanoscience, Network Science for Mobile Ad Hoc Networks (MANETs), Autonomous Sensing, Advanced Computing, Power and Energy and Graphene.

Success of the ARL DSIs will help ensure decisive warfighting superiority for our Soldier and enhance the foundation of our world-class laboratory.

Strategic Research Initiative in Neuroscience

Improving Soldier-system Performance



Dr. Laurel Allender

Director for
Human Research
and Engineering

The U.S. Army Research Laboratory's Strategic Research Initiative (SRI) in Neuroscience seeks to enable revolutionary advances in Soldier-system performance by integrating neuroscience with human factors, cognitive science, and engineering.

This multidisciplinary approach will enhance our understanding of Soldier function and behavior within complex operational settings, a critical aspect of cognitive and systems engineering.

Increasingly, the connection between human experience and its biological bases are the foundation upon which we come to understand how we perceive and interact with the external world.

As Army operations continue to move into more dynamic and complex environments, understanding how Soldier cognitive abilities meet the increasing demands of these environments is crucial in the development of systems that ensure mission effectiveness and maximize Soldier survivability.

Along these lines, ARL's neuroscience efforts focus on the scientific study of the brain and mind, and specifically on fostering the translation of neuroscience research, across its broad spectrum, to military relevant domains. The methods and approaches of neuroscientific research have the potential to enable a high-resolution understanding of the Soldier's mind in action and thus to augment Soldier-system performance to levels that have previously been unattainable.

ARL seeks advances, both in the neuroscientific knowledge base and in its related technologies, which will move neuroscience out into operational environments to support the integration of the capabilities and limitations of the nervous system into Soldier-in-the-loop system design and development.

Ultimately this effort will lead to system implementations that exploit the capabilities of nervous systems, rather than simply depending upon the adaptive abilities of Soldiers, and radically improve Soldier-system performance.



Support to Current Operations

ARL takes a very active role in working with our RDECOM and Army partners to provide technical expertise and assistance in support of ongoing operations. ARL mission investments over time are bearing fruit as technologies are spun off for applications to Current Force capability gaps and requirements. The full spectrum of ARL support provided includes developing technology solutions to solve current-force issues, technical field assistance for fielded equipment, training troops to use the fielded prototypes, and analytical support.

Persistent Threat Detection System with Airborne Acoustics

The Army Research Laboratory successfully developed and fielded one aerostat-mounted acoustic sensor array which detects, locates, and cues a collocated imager to transient sounds, such as mortar and rocket launches, and calculates the ground coordinate for the threat.

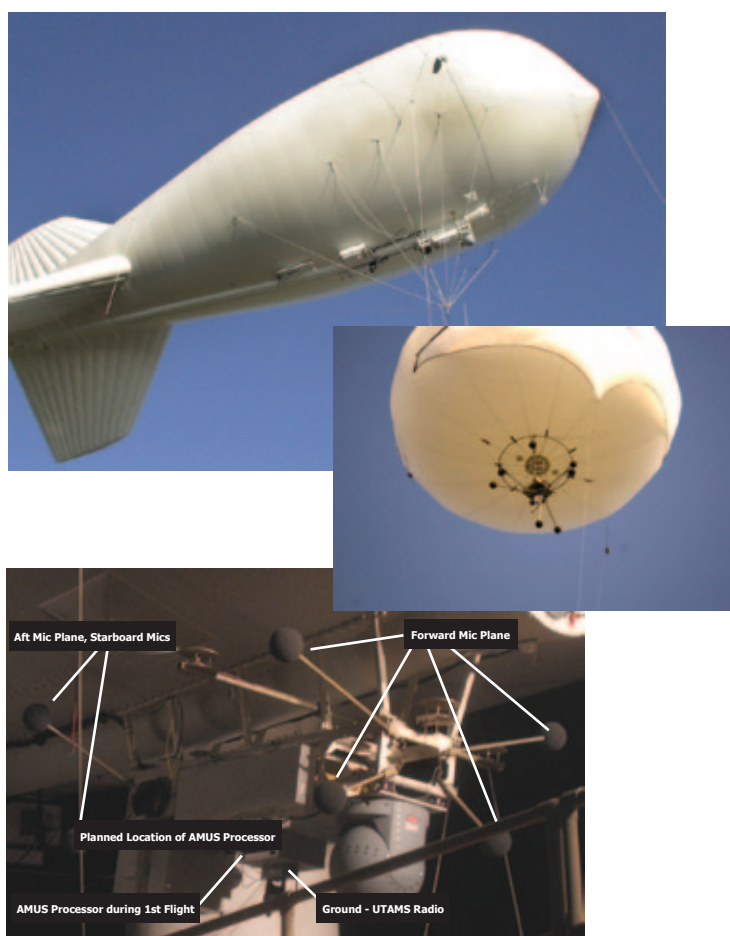
The addition of this unique airborne detection, localization and cueing capability will provide more accurate intelligence about mortar, rocket and improvised explosive device (IED) events.

By elevating a single acoustic array with a high-altitude tethered aerostat, better signal-to-noise for transients has been achieved to significantly increase the system's detection range over similar ground-based systems.

ARL demonstrated that the aerostat-mounted acoustic detection and three dimensional localization capability significantly improves the Army's ability to detect and defeat enemy mortar, rocket, and small-arms firing, and provides persistent acoustic surveillance for hostile events such as IED explosions.

This research led to a single airborne array with an integrated inertial navigation system and global positioning system which calculates a solution vector that intersects the ground and independently estimates a source location's coordinates while simultaneously cueing a collocated imager to capture activity at the target location.

This capability has never been demonstrated before on an airborne platform. ARL also demonstrated that tracking and cueing the imagers to helicopters, other aircraft and ground vehicles using the airborne array can provide additional important situational awareness information.



Additionally, ARL showed meteorological data can be used for wind-noise mitigation and solution vector compensation. The success of ARL's airborne acoustic payload led to the aerostat-mounted acoustic technology being incorporated as an enhancement to the Persistent Threat Detection System aerostats fielded by Program Manager – Robotics and Unmanned Systems and currently operating in Operation Enduring Freedom.

Joint Trauma Analysis and Prevention of Injury in Combat

Capturing Critical Lessons



Dr. Paul Tanenbaum

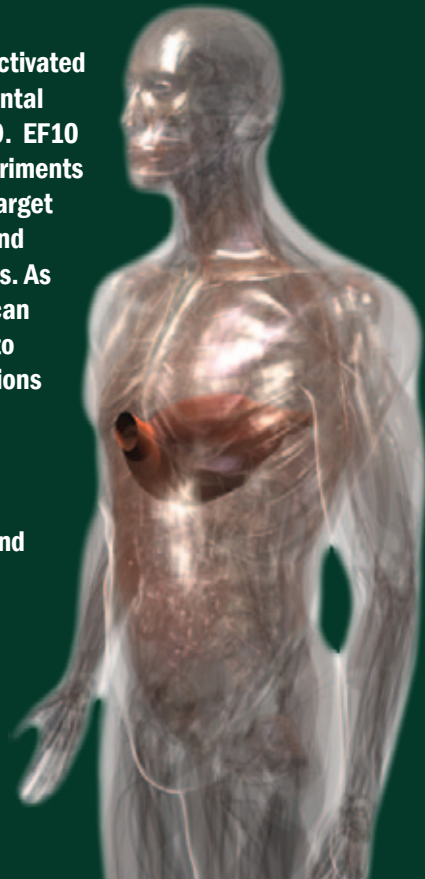
Director for
Survivability /
Lethality Analysis

In Iraq and Afghanistan, we face enemies who are lethal and battle-hardened, and many of our Soldiers have paid a heavy price. To ensure we capture the critical lessons bought by their sacrifices, the Department of Defense established the Joint Trauma Analysis and Prevention of Injury in Combat program, or JTAPIC. It's a highly novel partnership of materiel developers with the intelligence, operational, and medical communities, and it has tremendous value to all concerned.

ARL is a key partner in JTAPIC. For the first time ever, we receive detailed information about specific, actual combat events in theater, and we can respond by providing insights into the causes of Soldier injuries and expert advice on ways to reduce those injuries. Starting with our metallurgical analyses on the fragments recovered by combat surgeons, we conduct experiments on the interaction of specific threats and targets, and then, through computer simulation, analyze and reverse engineer individual battlefield events. Through this reverse engineering, we can explore solutions in a real operational context.

To support JTAPIC, we reactivated and refurbished Experimental Facility 10 (EF10) in 2009. EF10 allows us to conduct experiments to determine threat and target characteristics for IEDs and kinetic-energy penetrators. As a result, ARL and JTAPIC can be even more responsive to senior leadership's questions about theater events.

ARL and JTAPIC have gained insights about our Soldiers' vulnerabilities and have gone on to develop materiel solutions and support improvements to tactics, techniques, and procedures, all to mitigate or prevent these injuries in the future.



Thrown Object Protection System (TOPS) Kit

The vehicles used by U.S. Soldiers in Iraq and Afghanistan continue to experience ever-evolving threats to perform their missions. One such threat has been the constant exposure to objects thrown by enemy combatants. The Army Research Laboratory conceived and developed a Thrown Object Protection System (TOPS) kit.

The TOPS kits repel thrown objects through the use of an elastic screen that causes thrown objects to bounce back away from the ground system and its crew. These modular kits are extremely lightweight and easily customized to a wide variety of ground systems.

As of now, 88 percent of kits have been delivered to theater and 35 percent have been installed.

These systems have been fielded for end user evaluation and feedback.



TOPS System installed on MRAP 6 X 6.



TOPS System installed on MRAP 4 X 4.

Support to Current Operations

Exposures to Airborne Particles in Deployed Areas in Southwest Asia

Troops are frequently deployed to areas where the aerosol environment has not been well characterized. In Southwest Asia, very high concentrations of fine particles in the atmosphere raise concerns about potentially serious health effects on troops. A good understanding of the particle size distributions along with the chemical and biological make-up of the aerosols is needed to assess potential health impacts to Soldiers.



Deryck James makes adjustments to the aerosol sampler currently fielded in Iraq.



Soldiers utilize the aerosol sampler in Iraq.

The effort focused on conducting aerosol sampling in Iraq and Afghanistan as determined by mission needs and the U.S. Army Center for Health Promotion and Preventive Medicine (CHHPM) recommendation to characterize the aerosols currently impacting the Warfighter deployed in active combat zones.

The Army Research Laboratory worked with the U.S. Army Research, Development, and Engineering Command, Field Assistance in Science and Technology teams to deploy two novel aerosol samplers (drum impactors) in Baghdad, Iraq and one in Bagram, Afghanistan with complementary meteorological instrumentation. This effort was launched in coordination with the University of Alaska's Geophysical Institute in Fairbanks, "Airborne Threats." The time-resolved, environmental aerosols are being characterized by size, concentration, chemical composition and biological activity to determine their sources and potential impacts on Warfighters. Collected samples are brought back to the lab and analyzed.

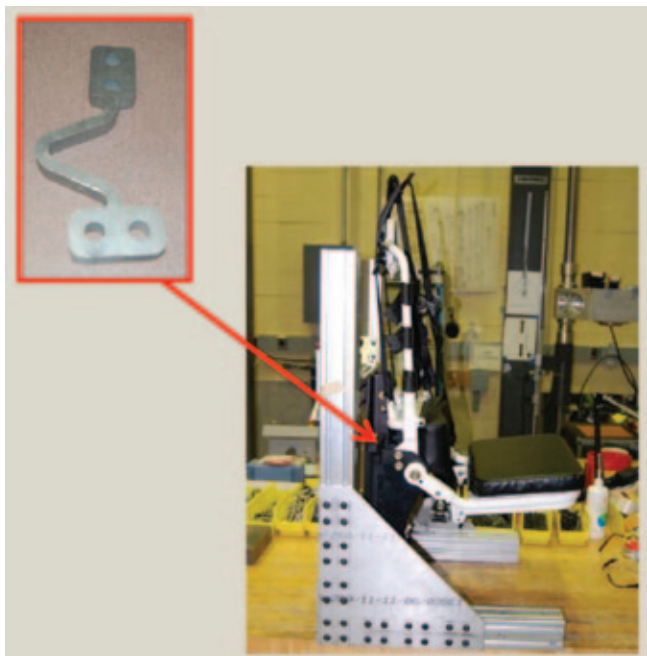
The data obtained from the sampler will help the military protect the health of the personnel at the site by identifying their occupational exposure to biological and chemical species, establishing a baseline and measurement of the natural variability of these species in an area, build a library of aerosol profiles and sources, and determine if a chemical or biological aerosol event impacted the site. CHPPM as well as other organizations throughout the Department of Defense's medical community are interested in mitigating the aerosol impacts and determining the potential health impacts of the aerosol exposure.

Expedient Crew Protection for Stryker Armored Vehicles

Continuing threats to ground systems from buried improvised explosive devices (IEDs) have led to major up-armoring efforts to improve protection for a wide variety of ground systems. Such improvements include the Stryker family of vehicles. Through the use of ARL's Defense Supercomputing Resource Center for supercomputing, materials research, on-site fabrication and live fire exercises at experimental facilities, expedient crew protection solutions for the Stryker were rapidly developed through the use of advanced armor materials and improvements in energy absorption for crew seating. These technologies were rapidly transitioned to General Dynamic Land Systems for kit production and fielding.



Expedient Stryker underside armor.



Improved Energy Absorption for Crew Seating.

Providing Armor Solutions for the Warfighter

MAWRS Achieves 40 Percent Reduction



Jill Smith

Director for
Weapons and
Materials
Research

As the Army's lead element for protection technologies, the Army Research Laboratory drives innovation providing critical armor solutions for the Warfighter.

An example is the success of the Mine Resistant Ambush Protected (MRAP) Armor Weight Reduction Spiral (MAWRS).

ARL closely monitored marked escalation in the lethality of threats encountered by forces deployed in Southwest Asia.

Background material available

suggested that the threats could be countered, but the state of armor technology was such that it would be too heavy for application to many ground vehicles. Forecasting the need for better and lighter protection, ARL developed aggressive weight reduction goals and set out to demonstrate technology options. During this same time period, the U.S. Central Command issued a Joint Urgent Operational Needs Statement creating the requirement for advanced protection.

With the MRAP vehicle currently in production, a unique partnership was formed between RDECOM and the MRAP Joint Program Office. The overarching mandate to the partnership was that the vehicle changes and introduction of armor production could not delay the highly aggressive deployment schedule of MRAP equipment to theater. The technical challenge to RDECOM was that the technology originally envisioned as high-risk to reach Technology Readiness Level 6 in a one-year program was now required to be production-ready within five months. The tight schedule was maintained and the resulting ARL developed armor technologies achieved a 40 percent weight reduction and were fielded on over 10,000 MRAP vehicles with spin-out designs provided to almost every major combat and tactical wheeled vehicle program currently in production.

These armor designs were developed in order to cover a large spectrum of cost, performance and material availability in order to meet the aggressive MRAP fielding schedule. The MAWRS generated dozens of armor designs to counter explosively formed penetrator threats. ARL scientists and engineers were recently recognized for the MAWRS success under the auspices of the Army's Greatest Invention program. ARL continues to improve technologies for the protection of Soldiers currently in harm's way.



Mission Accomplishments

The remainder of this review is structured around our nine technology focus areas of Extramural Basic Research, Networks, Human Dimension, Lethality, Mobility, Power and Energy, Sensors, Protection, and Survivability/Lethality Analysis.

The accomplishments presented here, while only a small sample of our efforts over the past year, are representative of the skill, dedication, and teamwork of our in-house staff and our partners in academia and industry.

Extramural Basic Research

- Direct Brain to Computer Interface Enables Firefox® Style Mind Control of Military Systems
- Advances in Virally Templated Flexible Batteries
- Self-Supervised Mobility-Based Terrain Classification for Unmanned Ground Vehicles
- Designing Mechano-responsive Polymers to Convert Damage into Useful Reactions

Networks

- Advanced Network Structure Formation for Mobile Ad Hoc Networks
- Asymmetric Core Computing
- New Wind Field Model Provides Detailed Information

Human Dimension

- Advanced Decision Architectures for the Warfighter: Foundations and Technology
- Neural Influences on Multi-Sensory Integration in Complex Settings



Lethality

- Very Affordable Precision Projectile (VAPP)
- Scalable Technology for Adaptive Response (STAR)
- Insensitive Munitions (IM) Technology

Mobility

- Durability of Advanced Barrier Coatings
- Autonomous Unmanned Systems
- Prognostic and Diagnostic Algorithms for Operational Readiness ATO

Power and Energy

- Microbial Fuel Cells
- 400 Amp, All-Silicon Carbide Switch Module
- Catalytic Combustors for Micropower Generation

Sensors

- IR Focal Plane Array
- Vision Protection ATO
- High Energy Solid State Laser

Protection

- Advanced Armor and Armor Materials
- Electromagnetic Protection System (EPS) Development
- Thermoplastic-Based Manufacturing for Improved Warfighter Head Protection

Survivability/Lethality Analysis

- Aircraft Survivability Against Man-portable Air Defense Systems
- Countering Asymmetric Threats
- ARL Demonstrates Virtual Shot Lines (VSL) Tool

ARL Investments in Academic Research

Producing Revolutionary Advances in Army Technology



Dr. David Skatrud

Director ARO
Deputy Director -
Basic Science

The foundation of current Army capabilities such as precision guidance, situational awareness, communications and mobility is the result of basic research carried out at academic institutions under Army Research Office (ARO) funding and guidance over the past decades. For example, lasers and the Global Positioning System (GPS) were enabled by Army research investments in atomic and molecular spectroscopy at universities.

ARO academic research investments continue to provide the Army with potentially revolutionary new capabilities for the future force. Investments in meta-materials may lead to cloaking capabilities that could render objects invisible. Investments in non-invasive brain interfaces could lead to thought control of equipment including prosthetic limbs and silent unspoken communications. Investments in quantum physics are leading to quantum computers that could speed up Army critical calculations required for code breaking and resource allocation by a factor of billions of trillions. Investments in matter wave optics are expected to produce laser gyroscopes that are a million times more precise than those existing today, which would provide a jam-proof navigation alternative to GPS, in addition to providing a wide variety of other capabilities such as detection of underground tunnels and bunkers.

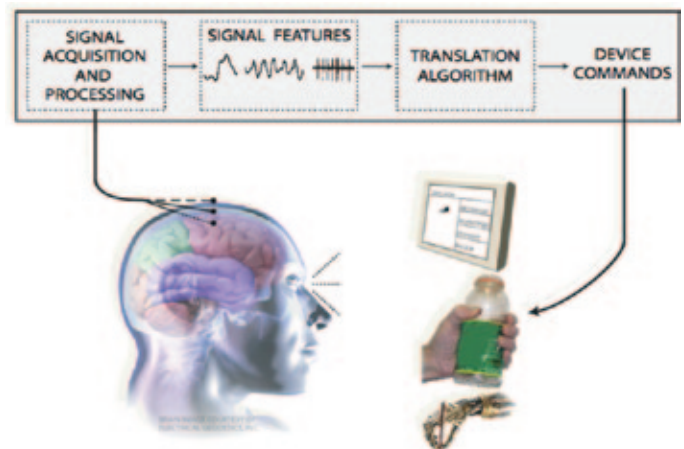
Similarly, investments with the Institute for Soldier Nanotechnologies at the Massachusetts Institute of Technology (MIT) and the Institute for Collaborative Biotechnologies led by the University of California, Santa Barbara will produce many critical advances for the individual Soldier. To cite just one such advance, researchers at MIT have created a genetically engineered, super-light-weight, high-power bio-battery that has the potential to greatly decrease the oppressive load of batteries carried by the dismounted Soldier. This invention was highlighted in a press conference by President Obama on green energy, and was tied to a follow-up personal visit the President made to the MIT laboratory.

Extramural Basic Research

Direct Brain to Computer Interface Enables Firefox® Style Mind Control of Military Systems

Multidisciplinary, basic research under the Department of Defense (DoD) Multidisciplinary University Research Initiative (MURI) program, which is sponsored by the Army Research Laboratory, led to the proof-of-concept demonstration of a small, implantable device that records signals from the surface of the brain (electrocorticography or ECoG) for translation into computer commands. Advances in the science underlying ECoG open a new avenue for data collection in neuroscience research. Direct readout regarding an individual's verbal intent and attentiveness has applications on the battlefield and in medicine. ECoG has a high potential for treating patients with epilepsy or other neurodegenerative diseases and control of prosthetic limbs. It also brings closer direct mind control of military communications, navigation, or weapons systems, as depicted by Clint Eastwood in the movie, *Firefox®*, where he used thought control to steal a radically new aircraft from the former Soviet Union and fly it out of Russia.

The new DoD research approach leads to a direct interconnect to the human brain that does not penetrate the brain, yet leads to major improvements in the signal quality of the brain activity interfaced to the computer.



The image displays the process by which an individual's thoughts can be translated into computer commands through ECoG.

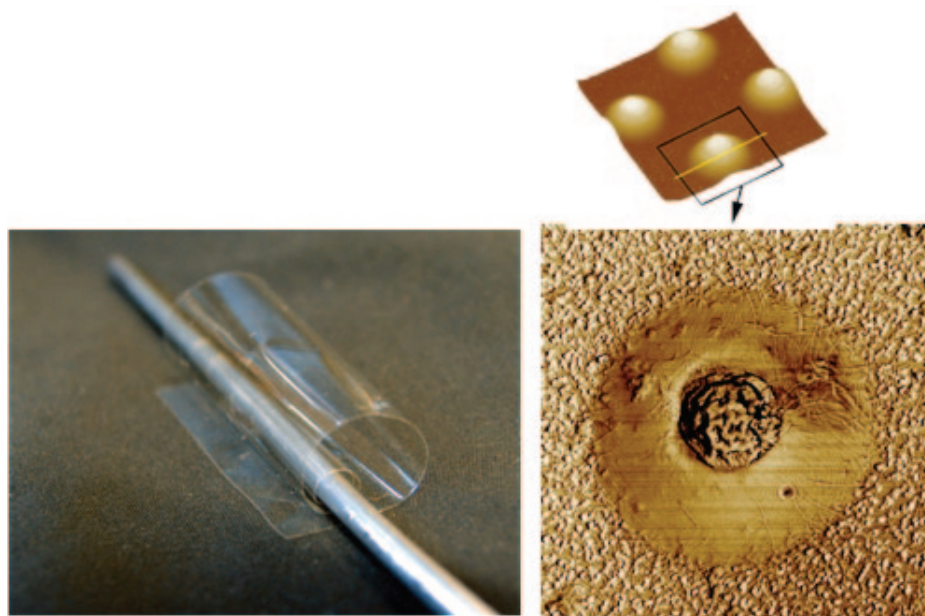
Advances in Virally Templated Flexible Batteries

Researchers sponsored by the Army Research Laboratory through the Institute for Collaborative Biotechnologies (ICB) have pioneered the use of biological systems to engineer batteries. The research team has used genetically-engineered bacterial viruses as templates for semiconductors and metals in controlled arrays, creating uniquely efficient, micro-scale batteries for Soldier personal power. Professor Angela Belcher, located at the Massachusetts Institute of Technology, is working with ARL and is focused on customizing the batteries for Army applications.

Most lithium-ion batteries are relatively bulky and must be enclosed within a hard, inflexible shell. The new batteries are lighter, retain their charge longer, and are more flexible when compared to existing lithium-ion batteries.

In this revolutionary route to thin-film, conformable batteries, genetically engineered phage were used to synthesize and assemble hybrid nanowires of cobalt oxide and gold at room temperature. Combining this virus-templated synthesis with a two-dimensional controlled assembly of the virus's electrolyte layers provided a systematic platform for integrating the nanomaterials to form thin, flexible lithium-ion batteries. Performance measurements indicate that the batteries have a capacity three times higher than that of currently available lithium-ion rechargeable batteries. The weight of a 10 cm x 10 cm transparent, flexible, self-assembled cobalt oxide-based battery made by this method is only 30 mg — an additional advantage over previous lithium-ion batteries. Collectively, the new improvements will lead to light and flexible power sources for the Soldier in the field.

Over the past year, a number of new electrode and electrolyte combinations were explored and the batteries were further optimized. In addition, many promising extensions of this technology began, including an integration of the batteries and the formation of methods concerning the development of ultra-capacitors, radio frequency identification (RFID) devices, and catalysts for the production of hydrogen fuel from water.



Stamped lightweight flexible batteries: Batteries were constructed from genetically-engineered templates. The diameter of the battery shown on the right is 3mm (i.e., three one-thousands of a millimeter).

Extramural Basic Research

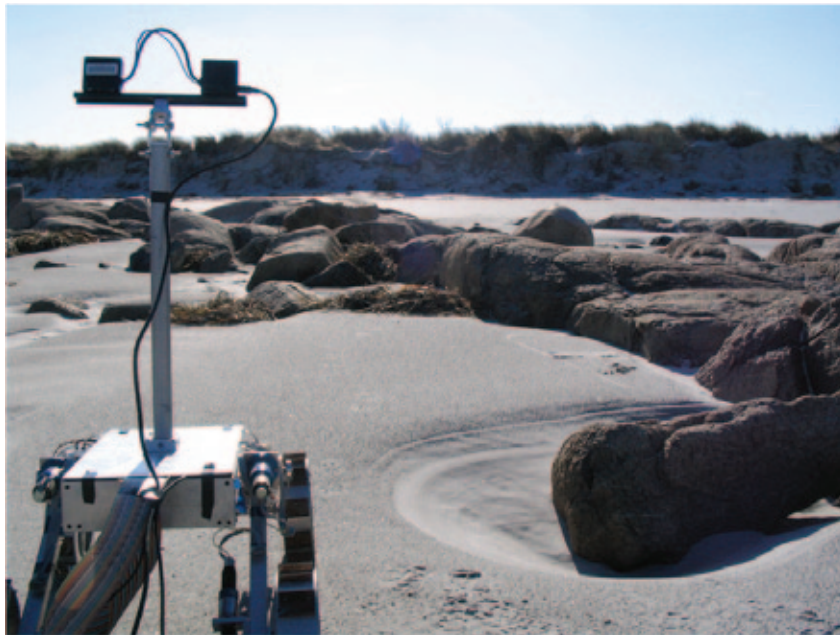
Self-Supervised Mobility-Based Terrain Classification for Unmanned Ground Vehicles

Unmanned ground vehicles (UGVs) will likely play an enhanced role in next-generation ground force operations. Potential applications for unmanned systems include asset transport (robotic mule applications), unarmed and armed reconnaissance, and improvised explosive device (IED) inspection and disposal.

UGV performance is significantly affected by the characteristics of terrain they encounter. The Army Research Laboratory supported research on terrain prediction. Classification is aimed toward developing a machine-learning capability for UGVs to remotely sense local and near-field terrain features and environmental conditions, predict mobility performance, and transmit the information to commanders in the field. Fundamental research on novel, theoretical constructs led to the development of algorithms capable of analyzing unexplored terrain.

A unique method for estimating the available traction and thrust for a particular terrain patch using the UGV's own drive train, in combination with onboard sensors, was developed. In this new approach, the UGV drives a single wheel at a specific slip ratio and then measures the resulting wheel torque and wheel sinkage. A constrained optimization framework is then used to bind the minimum and maximum thrust available from the terrain. To predict the mechanical properties of terrain several meters from the robot, a self-supervised learning framework was developed. It is currently being tested using the mechanical terrain characterization algorithm, along with a new vision-based terrain classification system. Extensive experimental characterization of the novel detection and thrust estimation algorithms were conducted in an outdoor, Army-relevant environment.

This research will make UGVs more capable and robust through new prediction capabilities and the establishment of terrain classes based on physical properties. Potential benefits from this research include the ability to deploy UGVs in diverse environments (i.e., urban, cross-country, desert, etc.,) without developing entirely new terrain sensing algorithms, and the ability to send UGV explorers to environments where terrain characteristics may be largely unknown.



Field tests: Machine-learning capabilities for an unmanned ground vehicle on sandy terrain.

Designing Mechano-responsive Polymers to Convert Damage into Useful Reactions

Discoveries leading to a more efficient use of energy on the battlefield are important to the Army and the Army Research Laboratory. The time and energy required for repairing damaged equipment or armor drains Army resources and, in some cases, can directly expose the Soldier to enemy attacks. The Army can benefit from basic research aimed at discovering new mechanisms for energy exchange. Figure 1 illustrates the “energy economy” and demonstrates how energy is manifested in a variety of “currencies,” such as mechanical, thermal or chemical energy. Basic research in the chemical and materials sciences can lead to the discovery of mechanisms that allow an automatic exchange of energy between these currencies — providing tools for efficient force protection.

Researchers, sponsored by an ARL Multidisciplinary University Research Initiative (MURI), demonstrated for the first time that polymer composites can be designed in solid materials at the molecular level to detect mechanical stress and self-repair after damage. Normally, mechanical stress applied to polymer composites forms cracks deep within the structure. Unfortunately, this type of damage is difficult to detect and repairs are almost impossible, rendering the material unsafe. This newly-developed class of materials can effectively respond to mechanical energy (e.g., damage) by automatically exchanging it for chemical energy (see Figure 1). These mechano-responsive molecules, termed “mechanophores,” are designed to convert mechanical stress into useful chemical reactions. Investigators sponsored by the program have designed a mechanophore, which successfully detects regions that sustain damage and visually indicates where damage occurred (see Figure 2).

Most importantly, these basic research results could lead to applications that benefit the Soldier, such as mechanophore-containing parachute lines that produce a cautionary color change when the lines have been stretched beyond the safety requirement, or a self-repairing armor in which various mechanophores illuminate the damaged area, repair the damage, and then return to the original color, confirming that damage was repaired.

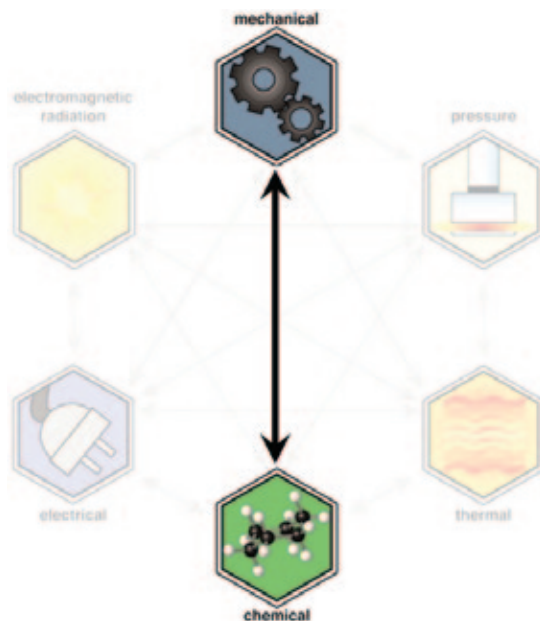


Figure 1. Energy exchange from one source to another in the “energy economy.” Discovering methods to exchange energy between the various currencies, such as mechanical and chemical energy, can provide an efficient combination of improved force protection and reduce the time required for equipment repair.

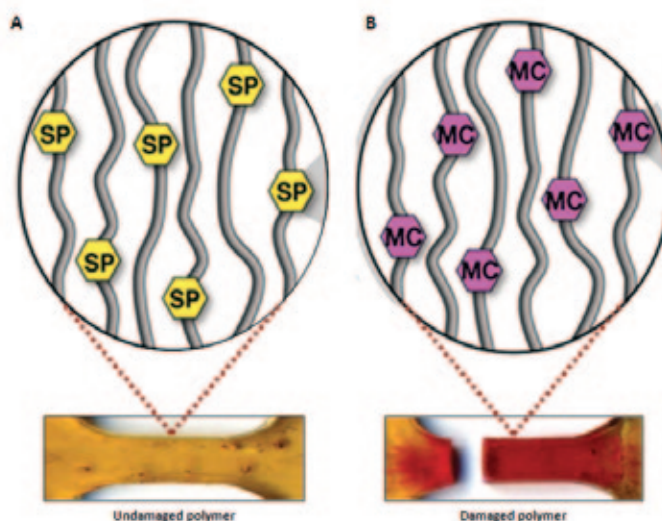


Figure 2. Mechanophore successfully self-senses damage. ARL/ARO-funded research directly led to the first ever demonstration of a solid that, due to the functionality of a mechanophore, can sense mechanical stress and produce a visible color change. (A) In the undamaged state, mechanophores within the polymer are colorless. (B) However, when the polymer is damaged (stretched), energy released from the mechanical damage causes a chemical change within the mechanophores, producing a red color. The red color increased in intensity until the polymer failed, and could be used to provide a mechanism that alerts a Soldier to materials that are damaged beyond safety limits (e.g., parachute lines).

Networks

Advanced Network Structure Formation for Mobile Ad Hoc Networks

Researchers in the Communications and Networks Collaborative Technology Alliance have made significant progress toward their goal to develop the underpinnings for dynamically self-configuring wireless network technologies that enable secure, scalable, energy-efficient and reliable communications for command on-the-move.

Collaborations between the Army Research Laboratory, the Communications-Electronics Research, Development and Engineering Center (CERDEC), academia and industry researchers are focused on three main thrusts: 1) survivable wireless mobile networks, 2) secure communications, and 3) tactical information protection.

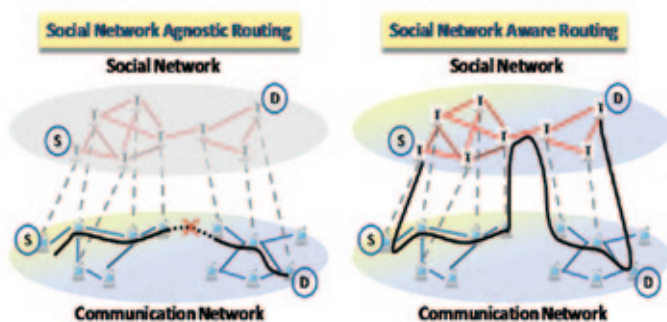
These collaborations have developed techniques, metrics and tools for the combined analysis of communications and social networks. These techniques significantly advance the state-of-the-art in modeling, designing and analyzing flexible network structures that have predictable performance in highly dynamic networking environments.

consideration during the assessment and formation of integrated networks structures.

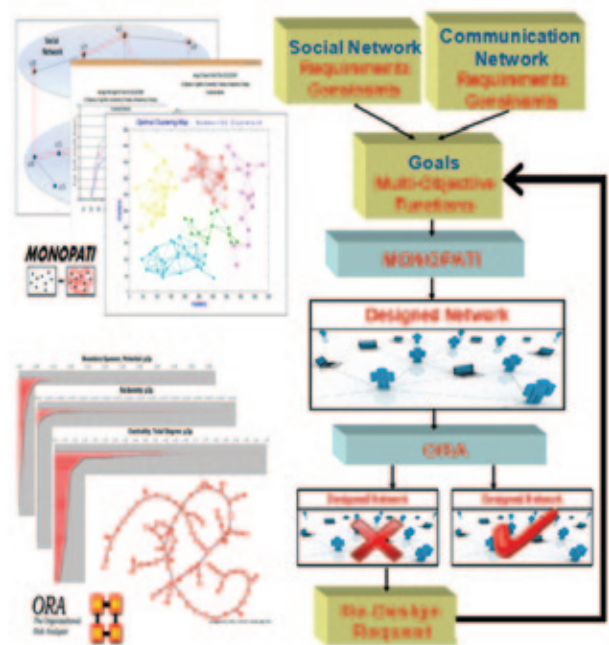
The software prototype integrates Multi-Objective Network Optimization and Assessment Tool (MONOPATI) with the Organizational Risk Analyzer (ORA) tools in a closed feedback loop.

This provides a versatile and formal framework for the formation, maintenance and assessment of efficient and survivable network structures that: 1) account for network heterogeneity, 2) give designers an understanding of structure benefits and costs, 3) enables automatic configuration upon arrival in theater, 4) rapidly adapts to changing environments and goals, and 5) considers diverse communication and social networks.

These tools have been applied to the establishment of disruption tolerant routing paths that use both communications and social network links so that end-to-end communication is ensured. These techniques and tools are being transitioned to the CERDEC Network Design Program.



During FY09, an integrated analytical framework and software tool was developed for the combined analysis and design of communications and social networks structures. This extended analytical framework involves the enrichment of metrics and cost functions so that communications and social network impacts and their interactions are captured, formally represented and taken into



Asymmetric Core Computing

The Army needs mobile, adaptable, cost-effective, high-performance computing solutions to facilitate efficient processing for increasingly digital and networked battlespaces.

The binary computing field is rapidly evolving, driven largely by market forces and physical limitations in current processor fabrication techniques. This evolution has the potential to provide scalable processing power to tackle many of the Army's processing needs. However, the emerging processor options are asymmetric and various computing cores often have differences more pronounced than their similarities.

The Army Research Laboratory is engaged in novel algorithm design, analysis, and hardware control strategy research to provide unique solutions within a complex asymmetric core computing approach, thus bringing supercomputing levels of performance to Soldiers and commanders in operational settings. ARL does this by focusing on a methodology that uses resources such as task parallel, multi-core computer processing units (CPUs), customizable circuit devices such as Field Programmable Gate Arrays (FPGAs), and highly multi-threaded data parallel computing assets such as Graphics Processing Units (GPUs). By focusing on commodity resources, ARL's paradigm remains flexible and low-cost throughout the lifecycle.

A customized hardware approach is also being developed to field small footprint asymmetric core workstations with high floating-point operation performance (FLOP). Customized designs in the size of a standard workstations are leading toward FLOP performance approaching or even surpassing supercomputing clusters of von Neumann CPUs that are usually stored in large computing facilities.

ARL's research team is developing new approaches for algorithm formulation and optimization in the complex tasks of distributing and mapping computational requirements to an integrated runtime system, which features asymmetric core resources.



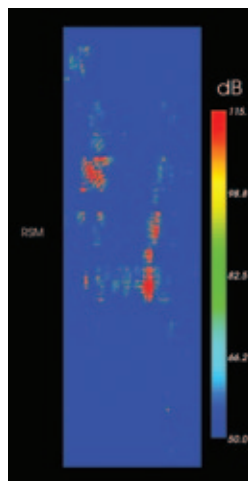
James Ross working on a state-of-the-art CPU.

ARL succeeded in developing real-time signal and image processing approaches for obstacle avoidance and concealed target detection.

ARL's asymmetric core solution is executing 610 times faster than the baseline Matlab implementation, and 38 times faster than single-core C implementation. Electromagnetic wave propagation models have been developed for asymmetric resources (40 times over single-core CPU solutions) that will allow for commanders to better plan and optimize mobile ad hoc communication networks. Real-time ballistic threat assessment and reduction models are being developed by blending

ray tracing approaches for asymmetric cores and urban/terrain models.

These demonstrations represent a significant breakthrough in advancing both the capability and the capacity of computing in operational environments. New applications and opportunities continue to emerge at every level.



The back-projection image formation time requirements for 274 meters of acquired data are shown.

Networks

New Wind Field Model Provides Detailed Information

The Army Research Laboratory developed a new 3-D wind field (3DWF) model to support military applications that need detailed meteorological microscale wind field information, especially in mountains, forests and urban areas.

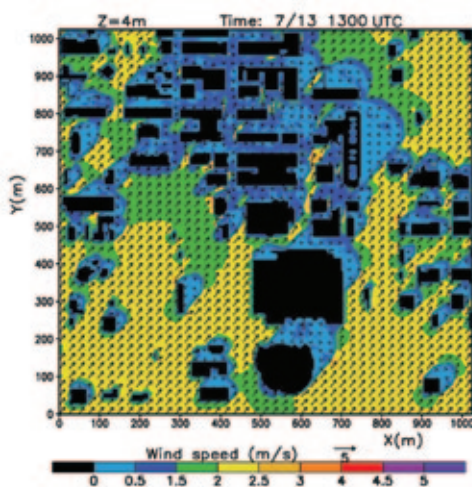
With the implementation of stretched vertical coordinates, immersed boundary conditions, and new Poisson solver to improve the 3DWF in complex terrain and urban canyons, the 3DWF model can maintain good accuracy, even for near surface, mass consistent wind flow while executing rapidly in nearly real-time on a personal computer.

The meteorological microscale includes wind features with spatial sizes on the order of meters or less and dynamic changes taking place over minutes or less in time. The 3DWF model was developed to address those scales for application to military operations. For example, in mountainous Afghanistan helicopter pilots will often find that operations are routine on one side of a ridge but impossible on the other due to winds and turbulence.

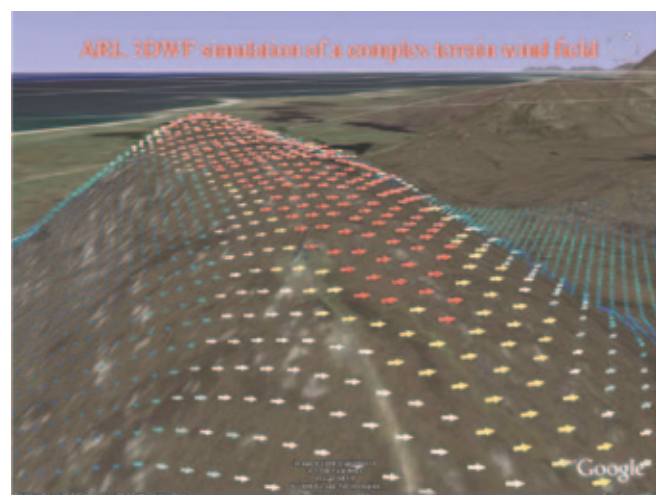
Other applications are wind data needed for the prediction and backtracking of biological, chemical and nuclear materials in the atmosphere for force protection; effective employment of military screening obscurants; prediction of wind and turbulence effects on electro/optical and acoustic wave propagation in the atmosphere for target acquisition and detection; turbulent wind effects on Unmanned Aircraft System control; and for accurate planning of paraprop operations including leaflet dispersal.

U.S. Air Force Combat Weather Teams, deployed alongside the U.S. Army throughout the world, retrieve daily operational weather products from the Joint Army/Air Force Weather Information Network (JAAWIN) originating from the Air Force Weather Agency (AFWA) at Offutt Air Force Base. However, the Air Force numerical weather prediction model forecasts often do not have enough spatial and temporal resolution to respond to fine scale features in terrain. Therefore, AFWA has requested 3DWF as part of our first ever transition of ARL developed weather information technology to the Air Force for inclusion on JAAWIN.

This technology transition was accomplished in 2009.



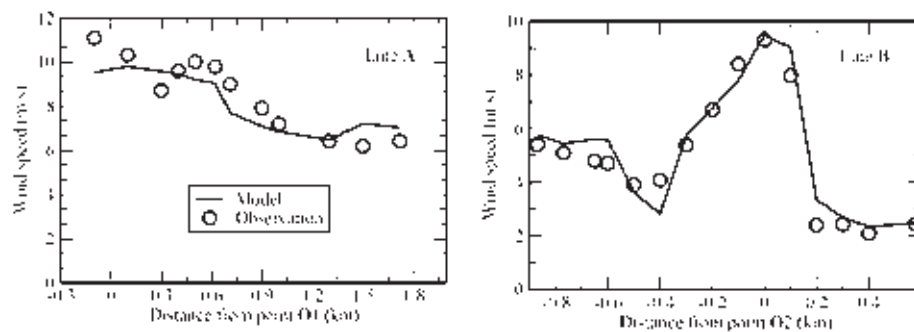
Example of 3DWF modeled winds at 4m height over Oklahoma City using Doppler wind lidar initialization. The black areas represent buildings.



3DWF model results (10 meters above the ground surface) over a complex terrain in Askervein Hill, Scotland.



Dr. Wang of ARL examines sonic anemometer instrumentation for validation of the 3DWF model. The 3DWF was used to design the new wind barriers for the Air Force High Speed Test Track at Holloman Air Force Base (shown in foreground).



The 3DWF results compare very well with two observational arrays along transverse and longitudinal lines over Askervein Hill, Scotland.

Human Dimension

Advanced Decision Architectures for the Warfighter: Foundations and Technology

The Advanced Decision Architectures Collaborative Technology Alliance (ADA CTA) has focused the innovative power of industry, academia and government researchers on the critical technology needs of the Army. The accomplishments are many and varied and include numerous technologies for Soldiers and commanders being transitioned, some are illustrated here.

In the first technical area, Cognitive Process Modeling and Metrics, cognitive processes were captured in qualitative and quantitative models. Questions about trust, especially in relation to technology, were explored and modeled to better understand the impact on performance. Software decision support agents constructed using a naturalistic recognition-primed decision making framework that is more robust than a strict utility approach were transitioned to the Tactical Human Integration with Networked Knowledge Army Technology Objective (ATO) for incorporation into an information and network management protocol.

In Team Communication and Collaboration, the second technical area, the goal was to create tools and intelligent systems that support collaborative decision making across distributed teams, that allows decision makers to share data in meaningful ways, and that allow decision makers to examine the impact of their decisions. This was accomplished on the one hand by understanding how individuals and teams make decisions, assess situations and interact with technology; and on the other hand, by prototyping and iteratively testing and validating collaborative software-based tools with actual Army decision makers such as the Collaborative SLide ANnotation Tool (CSLANT). CSLANT is a multi-media slide show created on the fly in the field where voice recordings are synchronized with pointing and with dynamic annotations made on a visual display and packaged in messages that support asynchronous or time-delayed dialogs, the result of which is vastly improved communication of factual content and intent.

The third area, Context-Sensitive Information Presentation, represents the state-of-the-art in presenting the right information to the Soldier at the right time. It includes cutting-edge display technologies such as tactile displays, multi-modal information presentation and flexible displays.



Context-Sensitive Information Presentation: Feeds from remote sensors or robotic systems must be designed to help the Soldier in the loop to reconcile imagery from ground and aerial perspectives.

Research on how the constraints such as network limitations, bandwidth restrictions impact the Soldier's ability to understand the situation and make appropriate decisions was transitioned to the Human-Robotic Interaction ATO. General guidelines developed for displays were published in a special issue of "New Insights in Human Performance and Decision Making," and comprise three major steps: 1) the selection of the modalities such as auditory, visual, and tactile, 2) the mapping of modalities to tasks and types of information including multiple perspectives, and 3) the combination, synchronization and integration of modalities.

The fourth technical area, Fusion and Intelligent Architectures focused on the management of resources through information fusion and intelligent architectures. These resources include physical entities such the allocation of robotic sensors. They also refer to the network itself and the communication links within it. The software policies such as the ADA CTA's agile software were developed to capitalize on available resources and to mitigate bandwidth and dropped link problems and to support commander timeliness and information requirements.

The ADA CTA research drew on a balance of emphasis on computer science, artificial intelligence, cognitive science and human factors research, all through the lens of naturalistic decision making. Key to the accomplishments and success of the ADA CTA was the adherence to the principle that in order to harness these technologies in a way that will help decision makers in the best way possible, we must conduct research to develop suitable system and software designs that work in consonance with human cognition and behavior.

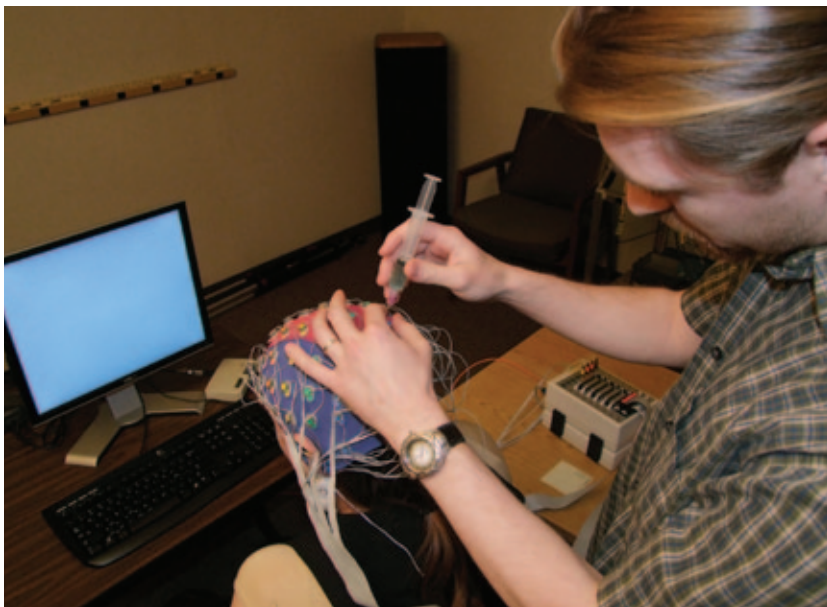
Neural Influences on Multi-Sensory Integration in Complex Settings

This project is the first in a new line of Army Research Laboratory basic research methods and tools that provide insight for later application of neuroscientific principles to operational environments. ARL is investigating the neural underpinning of inter-sensory integration, potential interactions between senses, and the development of physiological markers to monitor and use this information within operational environments. Soldiers are continually bombarded with information from many directions and senses – not only by potential threats in the battlefield but also from increasingly complex display and control systems.

Here, ARL has shown that when participants focus on a difficult task, the clarity with which background, non-attended sounds are represented in the brain depends heavily on whether they are working within the visual or auditory sense at the time. Importantly, this effect occurs at even the most basic levels of hearing, which has strong implications for the design of alerts and displays. Additionally, ARL has identified computational algorithms for assessing the amount of individual variation in the automatic “entrainment” of certain cerebral responses to these background sounds, which will allow an appreciation for differences in Soldiers’ abilities and limits of processing such complicated information.

Despite decades of research on how people maintain attention and associated brain states, there remains a lack of understanding in how the neural processes underpinning the allocation of attention actually affect function in complex, dynamic environments. This mostly stems from previous research being conducted within fairly limited laboratory settings, with the focus only on a single sensory system at a time.

Researchers use high-density electroencephalography (EEG) to assess varied levels of brain function while participants perform fairly difficult visual and auditory discrimination tasks. On- and off-line analyses then focus on the degree to which the non-attended sounds are processed at numerous levels in the nervous system, from initial reception to high-level computation.



Dr. William Hairston, a neuroscientist, applies high-density electroencephalography equipment to a research participant's scalp.



Dr. Hairston applies novel algorithms to electroencephalography data that are used to measure changes in brain state related to the allocation of attention while subjects perform visual and auditory tasks.

Continued testing aims to extend the findings to larger samples and establish the efficacy of the processing and identification algorithms for varied tasks and situations. An understanding of how the brain functions in complex, operational environments means that we can exploit this knowledge to effect better system design, which in turn could lead to improved Soldier performance such as more efficient multi-tasking, information processing and decision making.

Lethality

Very Affordable Precision Projectile (VAPP)

The Very Affordable Precision Projectile (VAPP) program enables low-cost, precision, indirect fires. This research is based on optimizing a fin-stabilized, rolling airframe. During FY09, flight testing was performed to verify structural integrity up to 12,000 gees and maneuver the projectile in various directions. Experimental data obtained during the firing tests showed that VAPP was able to extend the range 30 percent more than the unguided flight through gliding provided by a novel, single-axis canard actuation system.

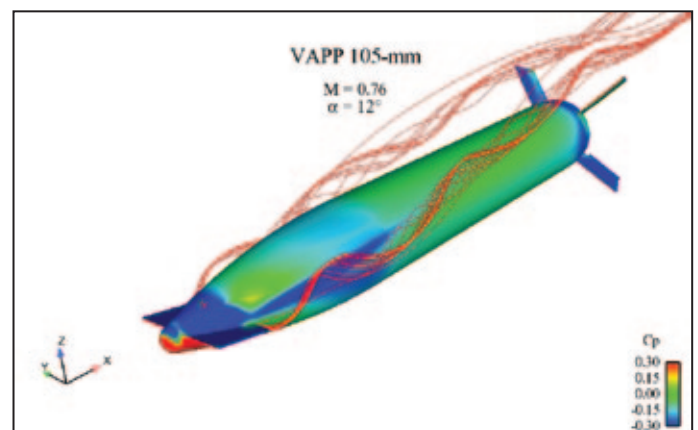
A gun-hardened global positioning system (GPS) provides information to a reduced-state guidance, navigation, and control (GNC) algorithm, which relies on a high-fidelity characterization of nonlinear aerodynamics. These technologies remarkably allow an order of magnitude reduction in the cost of precision munitions while providing similar accuracy by exploiting the fundamental flight dynamics of ballistic projectiles.



VAPP model: A launch and flight test bed was developed to support demonstration of VAPP technologies. The 105mm, fin-stabilized projectile shown is composed of a canard control mechanism, gun-hardened miniaturized electronics and embedded flight control algorithms. All components were developed and built at the Army Research Laboratory.



VAPP flight test: Free-flight experiments conducted at the Transonic Experimental Facility were the first to successfully maneuver a government-designed artillery projectile.

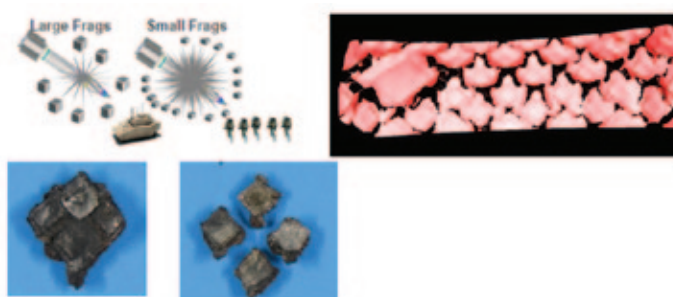


State-of-the-art computational fluid dynamics simulations were conducted to characterize the aerodynamics for flight testing and also supplied critical information to enable an affordable, reduced-state GNC system for VAPP.

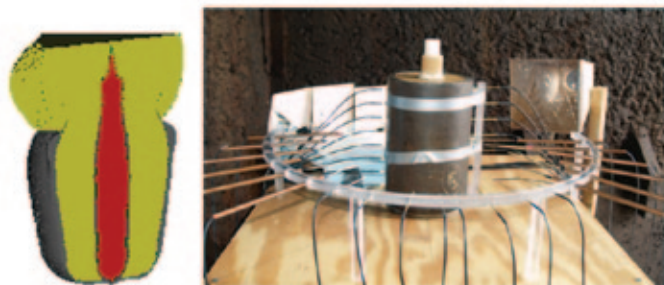
Scalable Technology for Adaptive Response (STAR)

Ground forces conducting military operations in complex urban environments currently do not possess the full flexibility, scalability and select ability of weapons that concurrently enable rapid overwhelming defeat while minimizing collateral damage and noncombatant casualties.

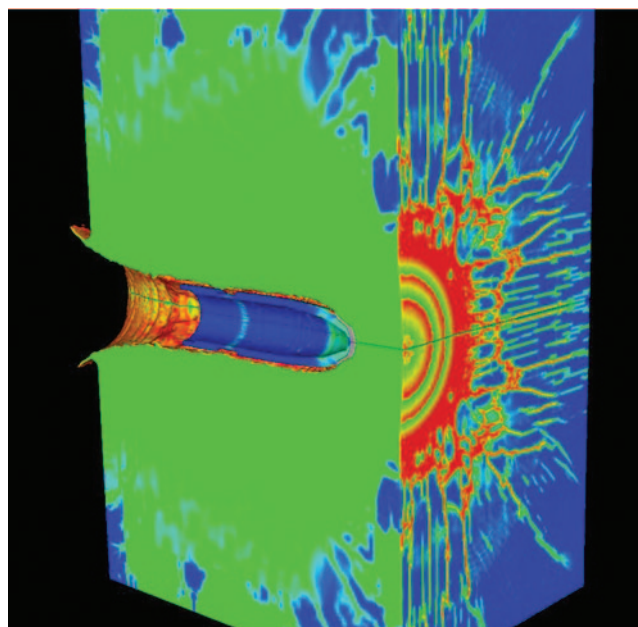
The Scalable Technology for Adaptive Response (STAR) program focuses on developing and demonstrating novel technologies that allow a single munition to adapt its response to selectively destroy target function and/or neutralize attributes while limiting damage to surrounding structures and personnel. The Army Research Laboratory's emphasis is on developing concepts and technologies to achieve variable explosive yield, selectable fragmentation, reactive materials research, and conceptualizing scalable warheads with various existing and novel technologies combined to achieve the desired effects on identified targets as determined through systems effectiveness studies.



Selectable fragment sizes for maximum effectiveness by in-theater selection based on target type.



Testing and Modeling and Simulation of Variable Explosive Yield Concepts developed at ARL.



Improved penetration of urban walls through advanced computational techniques and analysis.

ARL developed a scalable warhead concept that was selected by the Armament Research, Development and Engineering Center (ARDEC) as the top candidate concept for the artillery round demonstration for the STAR Advance Technology Objective (ATO). ARL and ARDEC, along with the U.S. Army Aviation and Missile Research Development and Engineering Center (AMRDEC) are currently working jointly on various technical challenges and research questions associated with the concept.

ARL developed and computationally demonstrated an improvement in wall penetration capability of an airburst round that is being developed under the STAR ATO. Recent ARL accomplishments also include successful proof-of-principle demonstrations of selectable fragmentation concepts that resulted in two patent applications, two different variable yield concepts, and enhanced blast effects.

Scalable technologies and concepts will allow for faster combat resolution in complex urban environments with customizable output with simplified logistics and minimized collateral damage.

Lethality

Insensitive Munitions (IM) Technology

The Army depends upon a wide variety of munitions to deliver decisive outcomes on the battlefield. It is imperative for these munitions to not only function in a safe and predictable manner, but to also react non-violently when subjected to unplanned stimuli during storage and throughout routine handling. The Army Research Laboratory led the insensitive munitions (IM) technologies as well as the Army Technology Objective through a joint program with the Armament Research, Development and Engineering Center (ARDEC) and the Aviation and Missile Research, Development and Engineering Center (AMRDEC). Through its technical contributions, ARL continues to further the survivability of the Warfighter and to increase effectiveness against a wide variety of threats.



Explosive Melt Casting Operation.

Recent enhancements, which focused on new vented designs and new energetic ingredients and formulations, were integrated into IM technology solutions for guns, missiles and warheads. In addition to improved materials and designs, predictive methodologies for sympathetic

detonation, fragment impact, and slow cook-off were developed concurrently.

Recent technology transitions include gun and rocket propellant findings from the Office of the Secretary of Defense's Joint IM Technology Program, a shaped memory retaining ring for improved venting to an Army missile system, and a vented warhead design for the 120mm Advanced Multi-Purpose Cartridge.



Experimental Set-up for Sympathetic Detonation Scenario on Munitions.



In-Process Explosive "Chips."

The enhancements and transitions in IM technology will ultimately improve tactical and combat system survivability, will aid in reducing transportation and storage burden, and will provide better tools for designing future munitions and weapon systems.

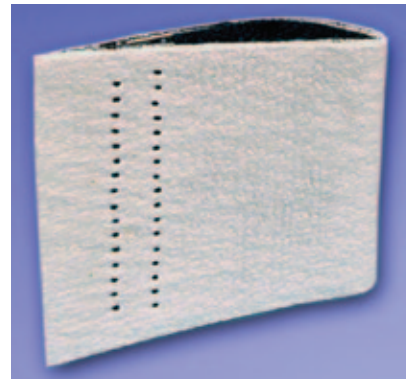
Durability of Advanced Barrier Coatings

An innovative, multi-layered thermal and environmental barrier coating (TEBC) system was developed to protect ceramic and ceramic matrix composite (CMC) engine components.

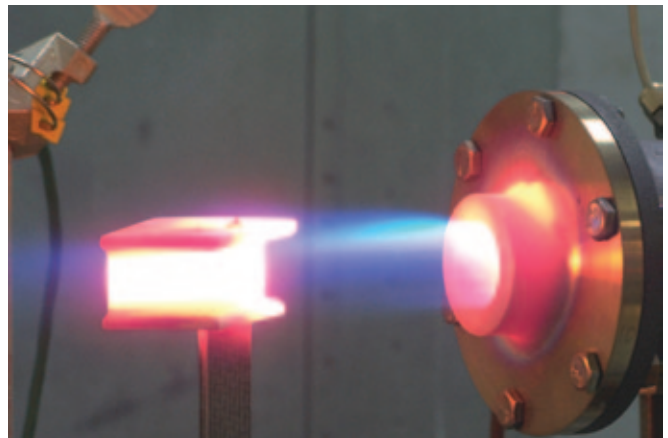
These TEBC coatings will make a significant increase in the engine operating temperatures and dramatically reduce the cooling requirements, which will translate to improved engine fuel efficiency and reliability. The coating consists of a multi-component zirconia-based or hafnia-based oxide defect cluster top layer, a strain tolerant interlayer, a mullite/rare-earth silicate environmental barrier layer, and an advanced ceramic oxide/mullite(+Si) bond coat layer.

The thermal and environmental barrier coating system provides an ultimate protective coating solution for silicon-based ceramic components exposed to very high temperatures and/or high gas flow velocity water vapor-containing combustion and erosion environments. The advanced defect cluster oxide top layer possesses low intrinsic thermal conductivity and an extraordinarily high thermal stability at temperatures up to 3,100 degrees Fahrenheit (1,704 degrees Celsius).

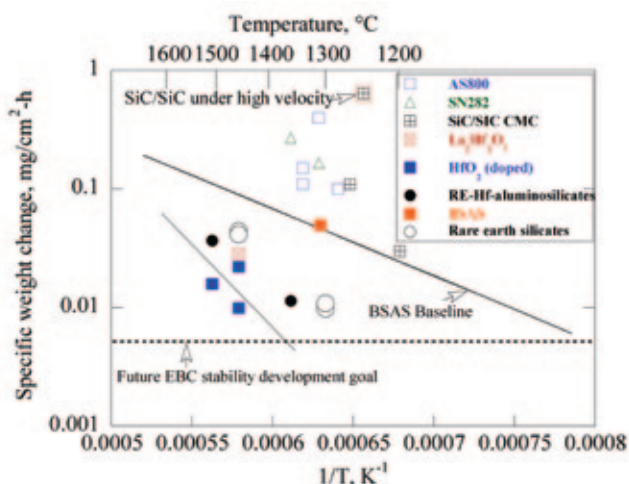
The oxide defect nanoscale clustering and the thermodynamically stable interfaces induce phonon scattering. As a result there is a subsequent reduction in thermal radiation conductivity within the coating system. The advanced interlayers impart a strain-tolerant buffer between the top layer and



Silicon carbide/silicon carbide (SiC/SiC) ceramic matrix composite turbine engine airfoil with multi-layered thermal and environmental barrier coating. The coating allows operation at higher temperatures and will result in improved engine fuel efficiency and reliability.



Durability testing of ceramic matrix composite with environmental barrier coating at high temperature.



SiC/SiC CMCs demonstrated higher stabilities in simulated engine high pressure combustion environments.

the substrate which allows it to accommodate large thermal gradient strains between the oxide top layer and the silicon-based ceramic substrate, enabling long-term coating and component durability.

The combination of the high-stability thermal barrier top layer and the sublayer environmental barrier provides excellent protection for Si-based ceramic and CMC components. The coating systems were evaluated in the high heat flux flexural fatigue test rig at temperatures up to 2,500 degrees Fahrenheit. CMC fatigue testing was completed and life models have been formulated.

The high heat flux interlaminar strength tests demonstrated potential to achieve component durability. Environmental stability was demonstrated at 2,700 degrees Fahrenheit in the high pressure burner rig. High heat flux cyclic durability was demonstrated (250 hours) at 2,700 degrees Fahrenheit.

Mobility

Autonomous Unmanned Systems

Future unmanned systems will be required to operate in dynamic, unknown and unstructured environments. In order to be effective, autonomous unmanned ground vehicles must be able to conduct tactically intelligent behaviors as a team member on the battlefield and be able to interact with Soldiers and civilians in a cooperative, adaptable manner.

The Army Research Laboratory and its Robotics Collaborative Technology Alliance have conducted advanced research in three key technology areas: perception, intelligence and human-robot interaction.

During FY09, ARL demonstrated new levels of autonomous mobility in structured and unstructured environments. In live experimentation, we demonstrated the ability of systems to autonomously maneuver both on- and off-road, appropriately reacting to changes in the environment.

ARL has demonstrated full utilization of a hierarchical control architecture, fusing vehicle-centric local perception and planning capabilities with mission level capabilities, to create autonomous functionality that more closely mimics a human driver than has never been accomplished.



Pedestrian detection demonstrated during data collection at the National Institute of Standards and Technology facility in Gaithersburg, Md.

Additionally, ARL has demonstrated full implementation of the 4D/RCS control architecture with bidirectional flow of information/plans during experiments performed at Fort Indiantown Gap, Pa.; demonstrated the ability of unmanned vehicles to apply pedestrian and vehicle detection and avoidance algorithms in order to autonomously maneuver in populated environments; and has developed an advanced hardware-in-the-loop simulation environment that has accelerated the pace of technology development.



Display from a simulation environment that was developed to evaluate and improve perception and intelligence algorithms.



Portion of live experimentation conducted at Fort Indiantown Gap, Pa., that included unknown obstacles that blocked paths and required the vehicle to plan and execute a new route to the objective.

Prognostic and Diagnostic Algorithms for Operational Readiness ATO

The Army is transforming its philosophy on maintenance of vehicular platforms from one that is schedule-based to one that is condition-based.

ARL has developed a key enabler for bringing this concept to fruition: an algorithm for prediction of remaining useful life of a vehicle propulsion component. The background for similar advances in commercial vehicles entails technologies that include vehicle computers that can tell you when to change your oil, vice blindly doing so at 3 months or 3,000 miles, as well as telematic-systems like On-Star™.

However, the Army's paradigm presents substantially more challenging environments in terms of the terrain, usage profile, required level of performance, and frequent operation outside of cellular telephone coverage. Advances in on-board sensors such as health and usage monitoring systems (HUMS) as well as ARL's remote sensor for ground vehicle application have also played key roles in the evolution of advanced diagnostics.

The primary technical challenge has been the development of the predictive algorithms themselves and determining a ground truth for the full progression to failure of component faults. By performing fault-seeding and on-rig testing of aviation bearings, ARL has assembled the necessary baseline data and capitalized on it with its advances in predictive algorithms that can now also be applied to fielded HUMS data.

Program successes include time-between-overhaul (TBO) extension of 250 hours for the AH-64 APU (Auxiliary Power Unit) clutch bearing. The savings from this TBO extension is estimated at \$1 million per year across the fleet.

The program has also resulted in the development of the first driveline prognostic for a relevant platform component, specifically the UH-60 oil cooler bearing. This algorithm also represents the first instance of prognostic software designed to be extensible to multiple components.

The combination of advances in feature detection for in-situ degrading components with sensing technology that both leverages and drives advances in the commercial sector are providing the impetus for expanding condition-based maintenance (CBM) capability from aviation into other sectors.

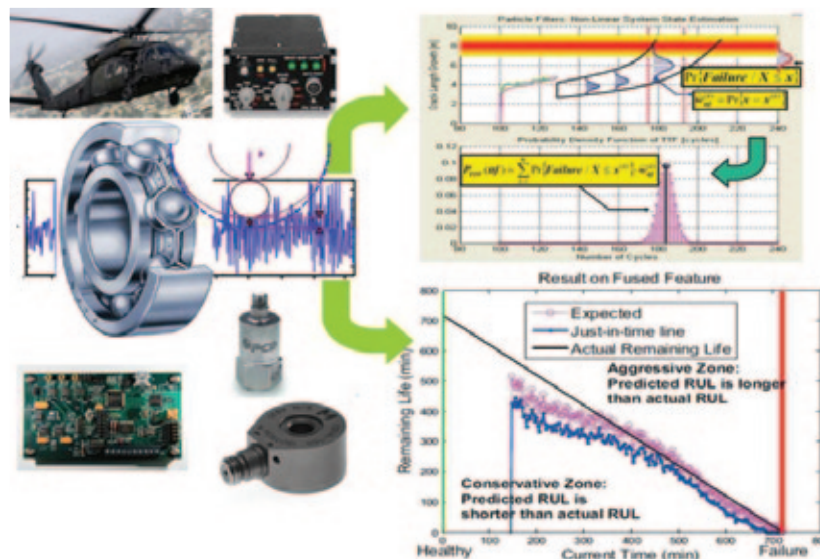


Illustration of the potential capability of Prognostics and Diagnostics (P&D) as applied to Army platforms. In this case, UH-60 Helicopter is used as an example to portray the P&D application. The P&D concept requires sensors and data acquisition systems to acquire data on a specific component, in this case, the oil-cooler bearing. Through the use of advanced signal processing algorithm, ARL can detect a fault and predict the remaining useful life of the component.

Power and Energy

Microbial Fuel Cells

Microbial Fuel Cells (MFCs) are bioelectrochemical devices capable of converting organic waste and environmentally available fuels into electricity and commodity chemicals.

The power density of MFCs is low when compared to batteries and traditional fuel cells however they have some advantages that make them a viable option for several niche applications. MFC-based technologies will likely rely on their ability to use indigenous organisms and fuels, remove waste, or monitor/alter microbial metabolism. Therefore the most promising MFC applications will be for power sources for unattended ground sensors, battery trickle chargers, self-powered sensors, waste mitigation and biofuel production. Technical barriers need to be overcome before these applications are realized but an ever-increasing interest in MFCs led to rapid progress in recent years.

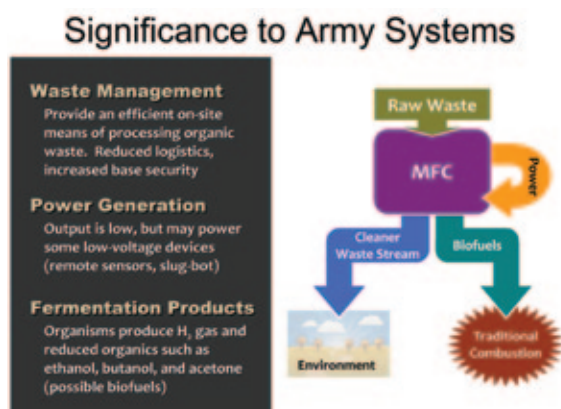
Research efforts at ARL have focused on organism-electrode interactions, electron transfer mechanisms, fermentation monitoring/control, and engineering of populations for optimal operation.

There are several pilot-scale MFCs in operation that have been designed to remove organic materials from industrial waste water, but industrial scale

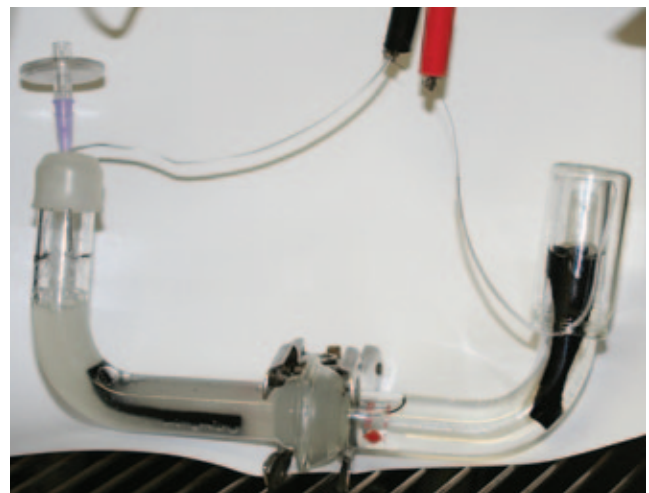


Cadet Caspar Yi, U.S. Military Academy at West Point, conducting research on microbial fuel cells at ARL during the summer of 2009.

MFCs are still many years away. This leaves a unique opportunity for the Army since it has some smaller scale applications which could be developed on a much shorter time scale. For example, MFCs could be used to power unattended ground sensors with environmentally available fuels, which would eliminate the need to replace batteries or whole sensors in dangerous areas. A more distant possibility is to use MFCs to mitigate waste at forward operating bases, thereby increasing security and decreasing the manual labor required for waste management.



Schematic showing how microbial fuel cells could potentially be used for waste mitigation and power production.



Two chamber microbial fuel cell typical of those used for research at ARL.

400 Amp, All-Silicon Carbide Switch Module

ARL has identified several technologies that will play critical roles in realizing the next generation of tactical ground vehicles. In order to meet anticipated ground combat performance requirements, high-power vehicle electronics will use inlet coolant temperatures ranging from 80 to 100 degrees Celsius.

Compared to conventional (silicon: Si) power electronic devices, silicon-carbide (SiC) devices offer higher temperature operation, higher breakdown voltage limit, and reduced losses. With Army Manufacturing Technology (Man-Tech) investment over the past four years, new SiC MOSFET transistors rated at 50 amps are now available in quantities that allow for development of full-scale components that meet system needs.

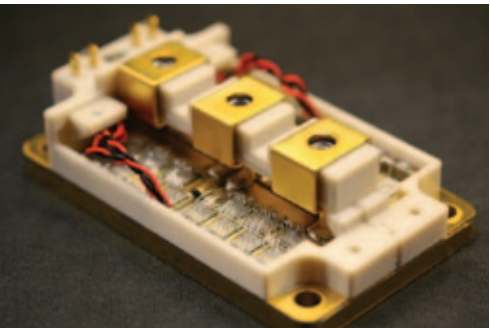
ARL has developed a 1200 volt, 400 amp, all-SiC power module using 50 amp, SiC MOSFETs and SiC Schottky diodes. These modules are now under evaluation for use in a wide range of DC-DC converter and DC-AC inverter topologies.

In addition to the improved electrical performance benefits realized by using SiC, these modules were developed with integrated, liquid-cooled heat exchanger having micro-channel or fin structures at the fluid-to-exchanger interface. This highly efficient structure allows heat to be conducted away from the transistors and dissipated in the coolant.

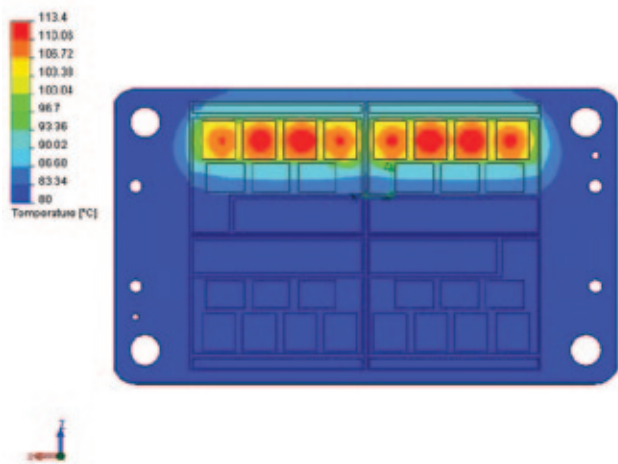
ARL is coordinating with the Tank Automotive Research Development and Engineering Center (TARDEC) and Army program managers (PMs) to promote the capabilities and potential performance improvements that are enabled by SiC. The next generation of converters under development at ARL boasts high-temperature operation of 100 degrees Celsius and a twofold increase in power density through the use of SiC power switches and advanced high temperature passive components.



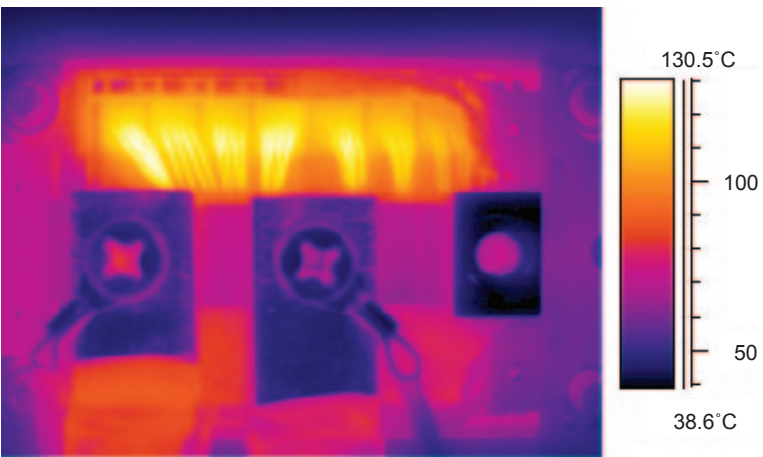
400 A module.



400 A module with lid removed.



Correlation between model (a) and experimental (b).



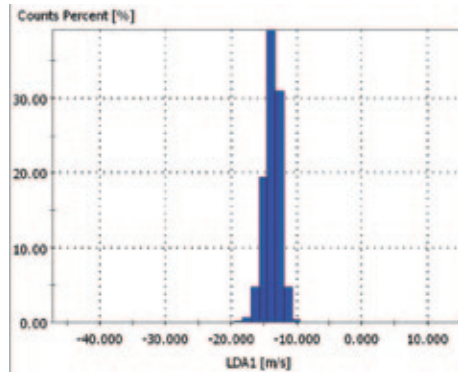
Power and Energy

Catalytic Combustors for Micropower Generation

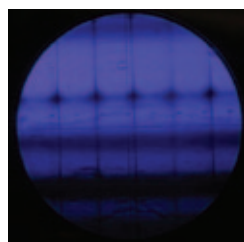
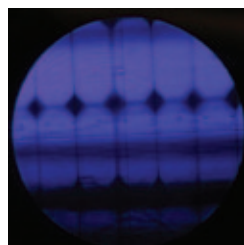
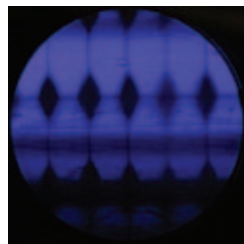
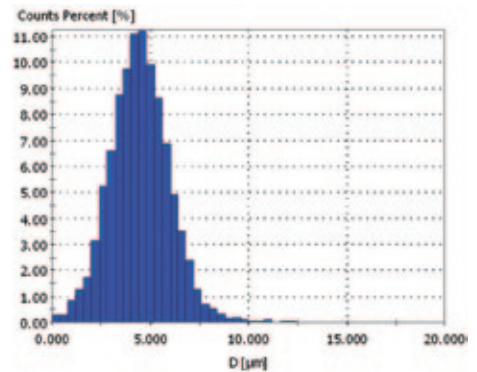
The Army has a need for small portable power systems to support a range of operations from Soldier power to unmanned aerial vehicles (UAV) and ground vehicles (UGV) applications.

The combustion of energy dense liquid fuels such as ethanol, butanol and JP-8 in a catalytic micro-combustor, whose temperatures can be used in energy conversion devices, is an attractive alternative to cumbersome batteries. While these combustors have the potential to outperform batteries, current technology limits system run time and reliability due to inefficient fuel-based energy conversion and poor fuel atomization at small flow rates (<10mL/hour). To improve system efficiency and reliability, ARL is developing micropower devices based on catalytic combustion and electrospray technologies.

To miniaturize the fuel combustor, an electrospray atomizer was utilized to inject ethanol or butanol droplets with diameter less than 10 μm . Butanol is easily



PDPA histogram for ARL MES 75-micron OD at 6 mL/hour.



Cone-jet shadowgraphies of MES: silver bullet (a); regular cone (b); and tilted jet (c).

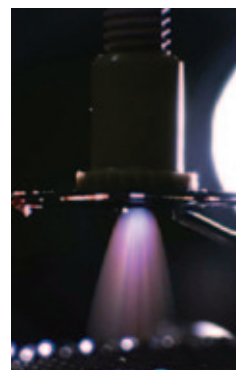


Ethanol catalytic combustion using six nozzle Micro Electro-Mechanical Systems electrospray atomizer.

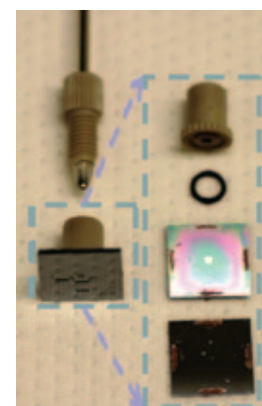
available through fermentation of biomass and is a common ingredient in domestic and agricultural wastes. Using rhodium-coated alumina foam, 100 percent conversion of ethanol and 95 percent conversion of 1-butanol were achieved under fuel lean combustion conditions.

ARL has shown that a single device can combust completely for thermoelectric applications, operate as a fuel reformer to produce hydrogen gas for fuel cells or perform as a bio-refinery for paraffin and olefin synthesis.

Through a cross-division joint effort, ARL is utilizing these combustion results to build a portable power device which is comprised of a fuel combustor and a novel PbTe-based thermoelectric device designed by ARL. These activities are part of the Power for the Dismounted Soldier Army Technology Objective in collaboration with the Communications-Electronics Research, Development and Engineering Center and the Natick Soldier Research, Development and Engineering Center.



ARL 19 nozzle MES.



ARL Micro Electro-Mechanical Systems Electro-spray (MES) assembly.

IR Focal Plane Array

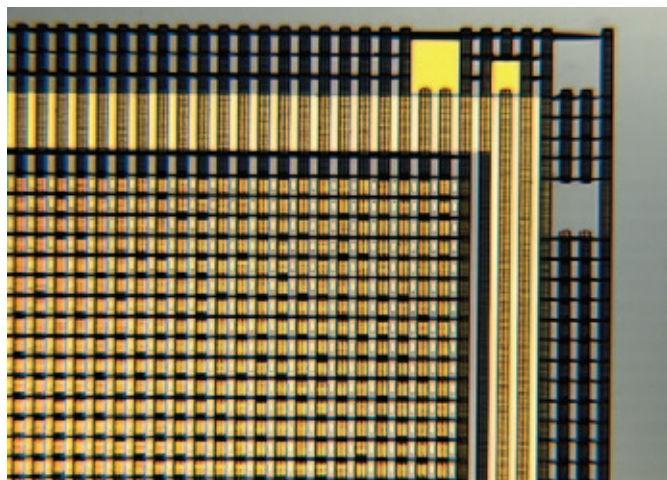
Infrared focal plane arrays (IR FPAs) are widely used in defense, science, and industry.

ARL is working on improving the resolution of these FPAs for a wide range of applications such as helicopter pilotage and large area surveillance. For high resolution FPAs, quantum well infrared photodetector (QWIP) is a promising technology because of its mature gallium arsenide material system and the availability of large area substrates.

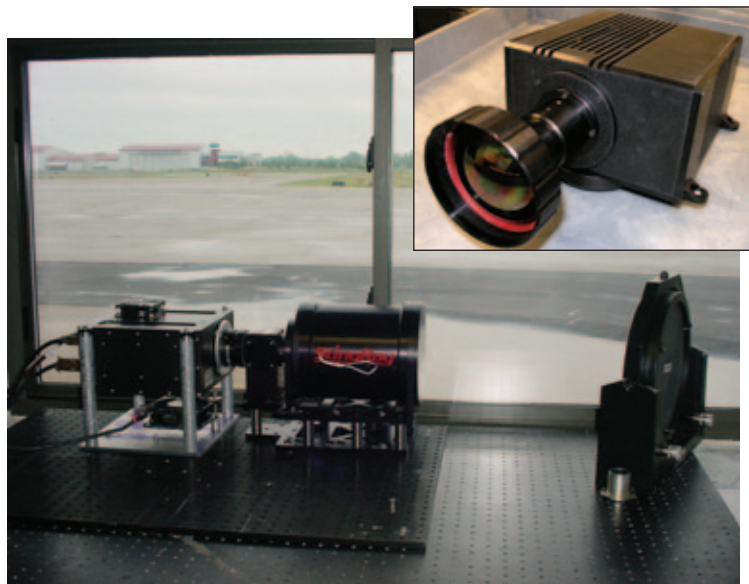
However, the commercial QWIP FPAs are still limited in both the size and the detection speed, which are caused by the delicate and inefficient grating coupling structures in the FPAs. To improve the FPA resolution and speed, ARL has investigated corrugated quantum well infrared photodetectors (C-QWIPs).

The C-QWIP uses inclined micro-mirrors on the detector sidewalls to reflect light into the detector active volume, eliminating the fine grating structures in the conventional detectors. The new detector improves the technology both in performance and in manufacturability. Because reflection is more effective in redirecting the light, the optical absorption is larger.

Reflection is also independent of wavelength. This means that the detector will preserve the natural absorption spectrum of the material, which can be much wider than the grating coupling bandwidth. Without the need for matching the material wavelength to the grating cavity modes in the detector, the same pixel geometry and production process are applicable to all QWIP material designs.



Close-up view of a C-QWIP focal plane array (FPA).



C-QWIP camera with a telescope for missile intercept observation.
Inset photo: C-QWIP camera.

This allows the simultaneous production of FPAs having a wide range of wavelength bands without jeopardizing quantum efficiency. In the absence of the fine grating features, it also allows the use of standard photolithographic techniques for faster, less expensive and very large format production. With all these benefits, QWIP technology is more capable of achieving high-resolution and high-speed imaging.

ARL, in collaboration with L3-Cincinnati Electronics, is preparing similar cameras for the Army Objective Pilotage for Utilities and Lift Army Technology Objective flight test scheduled in spring 2010.

Leveraging the same technology, ARL also supplied the required infrared sensors to NASA for the Landsat Data Continuity Mission scheduled to be launched in 2012.



Aerial image taken by two one-megapixel C-QWIP FPAs operating simultaneously, which shows their ability in helicopter pilotage and large area surveillance.

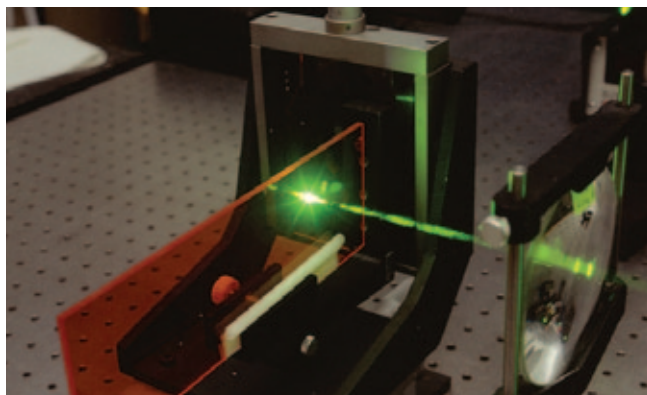
Sensors

Vision Protection ATO

The Vision Protection Army Technology Objective (ATO) is a collaborative four-year program to develop and demonstrate protection technologies to protect both Soldiers' eyes and charge-coupled device sensors from wavelength-agile, pulsed, battlefield lasers, as well as to reduce the optical signatures of third generation forward-looking infrared detectors.

Each of the participating Research, Development and Engineering Command partners (Tank Automotive (TARDEC), Natick Soldier (NSRDEC), and Communications Electronics (CERDEC) was responsible for developing technologies and hardware demonstrators appropriate for their mission areas, while ARL had the role of developing new materials and devices to transition back to TARDEC and NSRDEC.

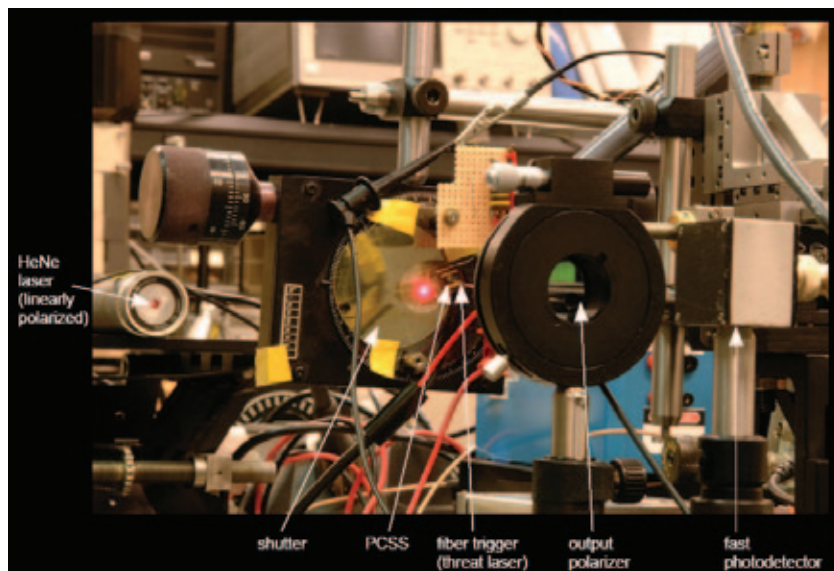
ARL, with its collaborative academic and DoD partners, has developed and demonstrated multiple unique technologies. ARL, with Penn State University, has developed multi-element arrays of magneto-optic materials coupled with photo-conducting semiconductor switches to be used as fast optical shutters. ARL, with North Dakota State University, has developed and characterized new organic nonlinear materials with very large excited state to ground



Conventional absorbing dye filter that is available for fixed-threat protection of the M1A1 driver's periscope. Absorbing dye filters do not protect against lasers operating anywhere within the eye/sensor bandwidth, but rather only against those operating in a narrow bandwidth region.

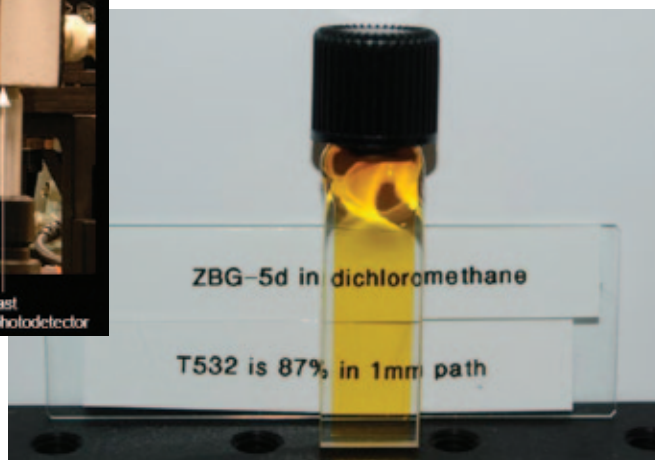
state absorption cross-section ratios (the measure of protection) that allow for wide bandwidth operation.

In addition, ARL, with the Naval Air Systems Command and the Laboratory for Physical Sciences, has developed new techniques for electro-optic material molecular engineering and processing, and was the first to electrically pole a thick electro-optic polymer. This is an important first step in the development of non-focal plane electro-optic polymer fast shutters.



An experiment to validate the use of an actively triggered electro-optic shutter. A photoconductive semiconductor switched activated by a chopped HeNe laser turned an electro-optic shutter (KD*P Pockels cell) on, reducing transmitted energy, in 1.4ns.

The Vision Protection ATO has been successful in pushing state-of-the-art laser protection technologies that can eventually be used to protect the myriad of Army optical systems, detectors, and most importantly, Soldiers' eyes.



Broadband nonlinear material.

High Energy Solid State Laser

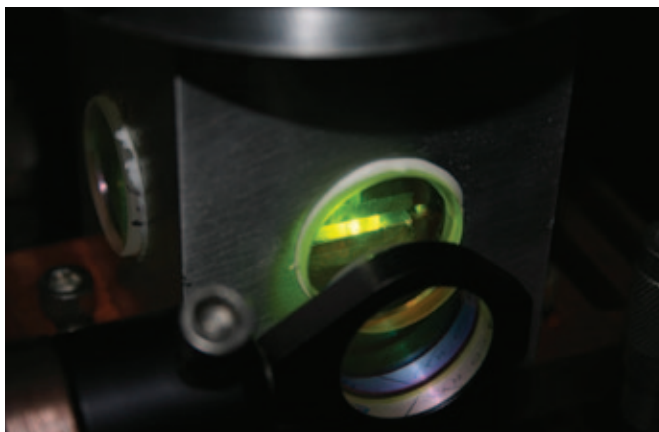
ARL conducts basic and applied research on novel solid-state laser concepts, architectures and components to enable High Energy Laser Technology for Army-specific directed energy weapon applications.

The goal is to demonstrate highly scalable approaches to diode-pumped solid-state lasers, which would allow power scaling toward the ~100 kW goal with the nearly diffraction limited (1.5-2 xDL) beam quality. Significant emphasis has been placed lately on eye-safer laser technologies, which warrant minimal collateral damage in urban battlefield scenarios. Eye-safer lasers emit at wavelengths which are readily absorbed by water so that their energy is absorbed in the front of the eye and does not penetrate to the retina.

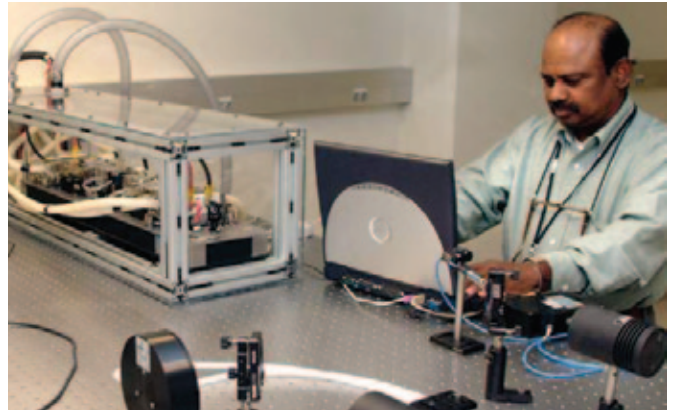
ARL's approach to highly scalable eye-safer laser is largely based on resonantly-pumped, ultra-low quantum defect laser schemes.

ARL achieved ~86 percent optical-to-optical efficiency operation of single mode Yb-free Er-doped fiber laser at 1,560 nm (quantum defect (QD) - of only ~6 percent) with diffraction-limited, single-frequency laser output.

This amplifier is believed to have the highest efficiency ever reported for Er-doped fiber amplifiers. The demonstration is a persuasive manifestation of feasibility of Er-doped fiber laser with nearly QD-limited optical-to-optical efficiency. ARL also achieved record high output power (of ~50 W)



Output window and the output coupler of the cryo-cooled (77 K) Er-doped Sc₂O₃ ceramic laser. Green glow is seen due to parasitic up-conversion process in the gain medium.



Dr. A. Michael preparing the software for testing room-temperature diode-pumped Er-doped YAG laser.

combined with the highest to-date optical-to-optical efficiency (of ~57 percent) out of resonantly cladding-pumped Yb-free Er-doped silica fiber.

Laser operation was achieved at 1,590 nm (quantum defect - QD - of only ~3.75 percent) with diffraction-limited laser output. This is the first resonantly cladding-pumped FBG-based Er-doped LMA fiber laser ever reported.

ARL also achieved the first resonantly-pumped laser action based on the 3F₃ → 3H₄ transition of Pr³⁺ ion. A Pr³⁺-doped laser in-line, pumped at ~1,547 nm, exhibited slope efficiency of over 21 percent at 1,676.5 nm despite the marginal quality of the laser sample available for this proof-of-concept experiment. So far, resonantly-pumped laser action in this spectral range was assumed to be possible only from Er³⁺- based gain media.

The demonstrated laser is believed to be the first “non-Er³⁺” resonantly-pumped ~1.6-μm eye-safe laser ever reported. These findings set a new path to a low-quantum-defect solid-state laser, which is realizable in laser host materials with low phonon energy (~200 - 250 cm⁻¹), so called “low-phonon hosts.” These materials so far were considered of interest only for Mid-IR applications.

This work supports a highly efficient scalable solid state laser effort towards high energy, high beam quality, eye-safer, directed energy laser weapon for the C-RAM application.

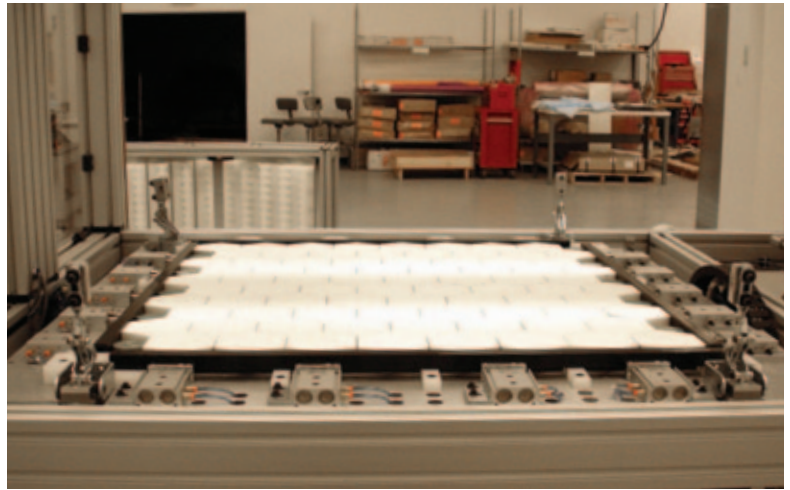
Protection

Advanced Armor and Armor Materials Development

The Army Research Laboratory continues to reduce the weight of armor technologies to defeat current and anticipated direct fire threats and develop efficient means to protect against land mine threats.

Recently, ARL developed a methodology for the analysis of loading from blast and penetrator mines for the development of ground combat vehicle concepts.

Defeat of future threats in developmental armor configurations was demonstrated, and ARL also developed and fabricated new materials for next generation armors. These materials are currently in subscale evaluations.



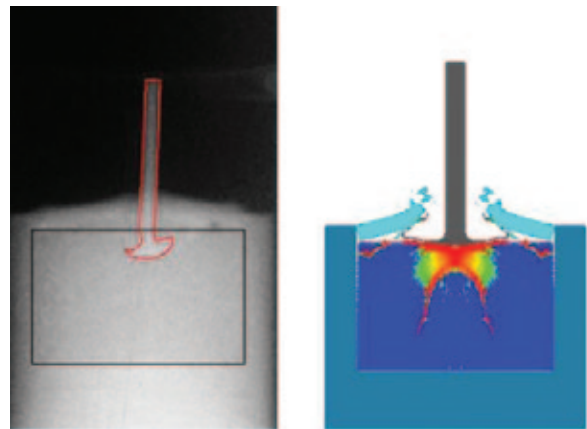
Build-to-print armor manufacturing technology.

These efforts demonstrate ARL's focus to reduce the weight of base vehicle armors and mission essential add-on armor packages. Lighter weight armors will enable tomorrow's combat vehicles to meet critical survivability and mobility requirements.

ARL Leading the Way – Advanced Armor Solutions for the Future



Occupant protection for mine-blast events.



High-intensity x-ray and numerical simulation of laboratory projectile interacting with a confined ceramic armor.

Electromagnetic Protection System (EPS)

Army vehicles in forward areas face continued threats from rocket propelled grenade (RPG) attacks. The required increases in protection have added considerable weight to systems impacting, mission loads, and overall system durability. To reduce these burdens, the Army Research Laboratory (ARL) developed, matured, and transitioned the Electromagnetic Protection System (EPS) technology, which is capable of defeating multiple impacts of unitary RPGs. In partnership with British Aerospace North America (BAE Systems), EPS was integrated onto mine resistant ambush protected (MRAP) platforms. End user trials will begin in 2010. This improved RPG defeat technology is critical for improved platform protection.

EPS – Improved Platform Protection Technology



Rear view of EPS system showing tight integration with existing MRAP design.



A demonstration of an MRAP all-terrain vehicle, (M-ATV) in Oshkosh, Wis.



MRAPs are offloaded from the Military Sealift Command roll-on/roll-off ship USNS Pililau (T-AKR 304) onto a pier in Kuwait.

Protection

Thermoplastic-Based Manufacturing for Improved Warfighter Head Protection

ARL researchers were instrumental in developing the manufacturing processes needed to produce the new Enhanced Combat Helmet. This new helmet is now scheduled for fielding to both the Army and the Marine Corps in July 2010.

This effort, funded under the Manufacturing Technology (ManTech) program, identified two critical technology barriers precluding the use of significantly improved ballistic materials in helmets, near-net performing methods, and rapid, cost-efficient thermoforming processes.

The program served as a catalyst for innovation, and common platform technologies were developed, demonstrated, and shared with the ManTech participants. Participants included British Aerospace North America (BAE Systems), Gentex Corporation, Mine Safety Appliances Company, and Diaphorm LLC.

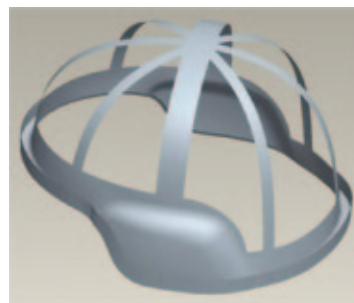
Technologies that were developed include a 100 percent automated preform system for accurate assembly of thermoplastic material, integrated rim stiffening for reduced part count and assembly time, and low thermal mass tooling for rapid heating, consolidation, and cooling of thermoplastic materials. The net result was a process capable of delivering 35 percent greater ballistic performance, compared to the current Army Combat Helmet baseline, using the new generation of ultra high molecular weight polyethylene materials.



David Spagnuolo, a materials engineer, talks to John Mullen, technician, about various types of materials while James Wolbert, technician, operates the hydraulic press.



Mike Neblett, technician, works on the automated preform machine.



Computer modeling rendition showing the concept of using a reinforced stiffener to enhance helmet stiffness.



Graphite/epoxy stiffener applied to a polyethylene/aramid helmet.

Survivability / Lethality Analysis

Aircraft Survivability Against Man-portable Air Defense Systems

Man-portable Air Defense Systems (MANPADS), an infrared (heat seeking) ground-to-air missile, have been manufactured and proliferated worldwide and pose a threat to military and civilian aircraft because of their ease of use.

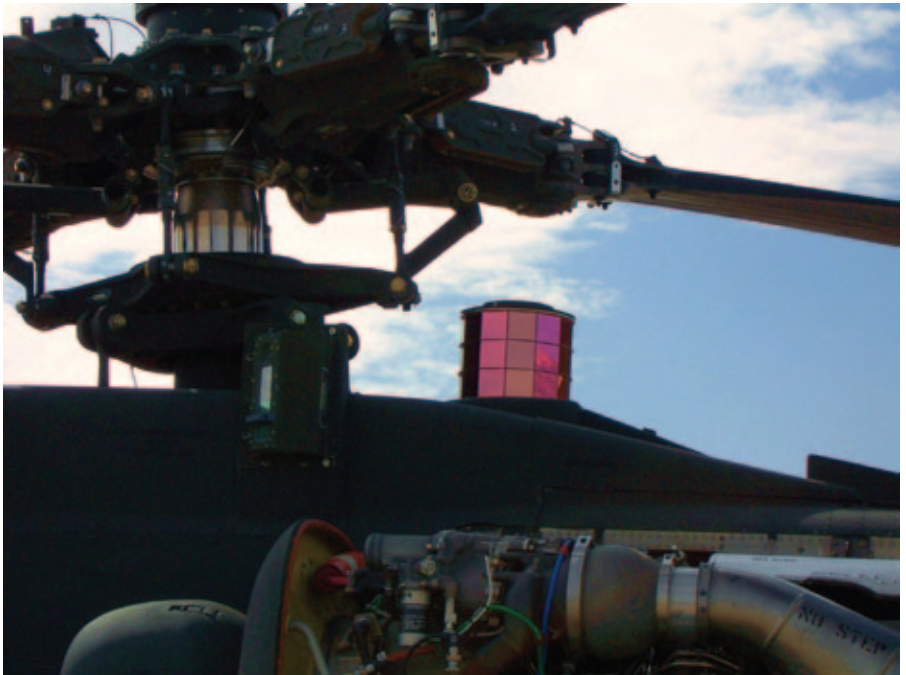
These systems are readily available on the black market and are attractive to terrorists because they are lethal, portable, concealable, and inexpensive. ARL uses hardware-in-the-loop modeling and simulation to develop and analyze both active and passive countermeasures for the protection of rotary and fixed-wing aircraft against MANPADS.

Two FY09 analytical efforts evaluating active and passive countermeasures were the AN/ALQ-144 performance study and the Joint Cargo Aircraft (JCA) PM support, respectively.

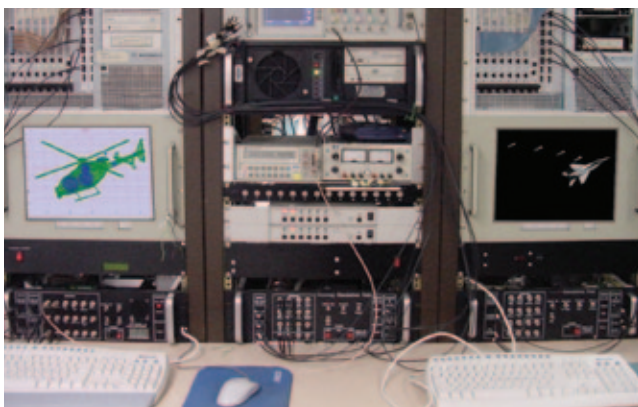
The AN/ALQ-144 system, currently being used by Army rotary aircraft in Operation Iraqi Freedom and Operation Enduring Freedom, is an active autonomously-operating infrared (IR) countermeasure jammer and is designed to protect military aircraft from air-to-air and ground-to-air IR missiles.

ARL addressed survivability issues on the AN/ALQ-144 for both Army and Marine Corps rotary aircraft by quantifying current AN/ALQ-144 effectiveness and using the results to optimize jam codes.

The JCA is a small cargo aircraft that provides responsive, flexible, and tailored airlift for combat, humanitarian operations, and homeland defense. ARL supported the JCA program office by leading a tri-service effort to select a passive countermeasure solution (e.g., flares) to enhance the aircraft's survivability against MANPADS threats.



An AN/ALQ-144 active infrared jammer mounted on an Apache helicopter. ARL develops detailed models of each countermeasure to investigate their effectiveness or in combination with other countermeasure types.



Computational hardware and electronics used to excite MANPADS missile electronics and collect data for analysis efforts.



ARL's MANPADS hardware-in-the-loop simulations are used to select passive countermeasures (e.g., flares) suites that will effectively protect aircraft.

Survivability / Lethality Analysis

Countering Asymmetric Threats

To counter hostile fire asymmetric threats, ARL is developing technology based on the specific sensor spectral response which is matched to threat signature characteristics.

A key feature in deterring the use of asymmetric threats is detection before impact at a low false alarm rate, allowing the opportunity for threat weapon engagement. A silicon-based prototype was produced and used to support field experimentations producing cogent results, indicating that low-cost solar blind detection is easily attainable. ARL researchers have shown that the weapons providing the enemy with key operation factors of mobility and concealment, which have translated into a large number of U.S. casualties, can be mitigated with low-cost silicon based imagers.

The threat offensive weapons of choice include Rocket Propelled Grenades (RPGs), mortars, and conventional small arms, which all possess a significant associated muzzle flash. The goal of this effort was to identify a detection solution that differentiated the muzzle flash from solar radiation



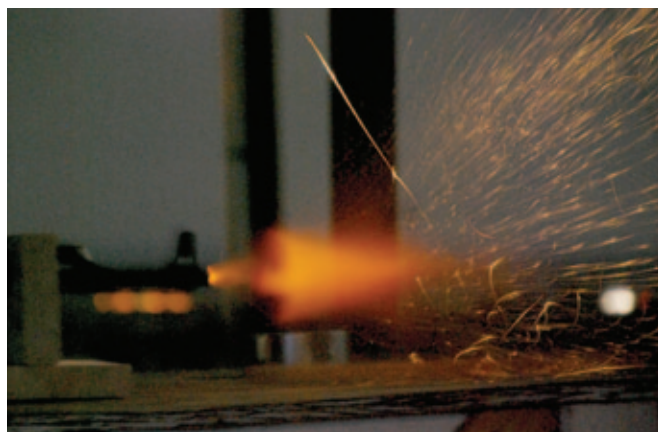
Sgt. Candelario prepares to fire a small-arms weapon. Measurement instrumentation is shown in the background.

and intermittent glint occurring from reflective objects, thus significantly reducing the single most prevalent source of false alarms.

Signature analysis conducted on muzzle flashes has advanced the development of silicon-based detection methodology, by mitigating solar effects through effective spectral filtering.



Erika Jackson, an ARL engineer, operates signature measurement equipment during field testing, which was used to measure mortar, small arms, and RPG signatures.



Long-time integration image of small arms muzzle flash taken during ARL signature measurements, which were used for emission characterization.

ARL Demonstrates Virtual Shot Lines (VSL) Tool

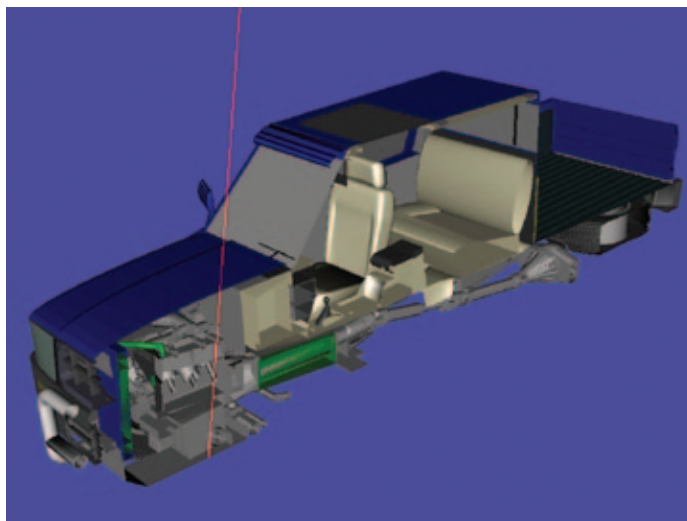
ARL has developed an interactive, graphical computer application to support live-fire test planning and ballistic analyses. The tool has proven useful in improving the quality of live-fire test plans and reducing the time and effort necessary to develop them.

The Virtual Shot Lines tool enables the user to view and interact with computer-based geometric descriptions for vehicles or other military assets. These descriptions are often generated by vehicle manufacturers using commercial design software. Using VSL, analysts, engineers and evaluators can visually navigate through the geometry, query the identity of objects, and select objects to be displayed or hidden. Shot lines through the geometry can be generated by a simple mouse click or by specifying numerical parameters.

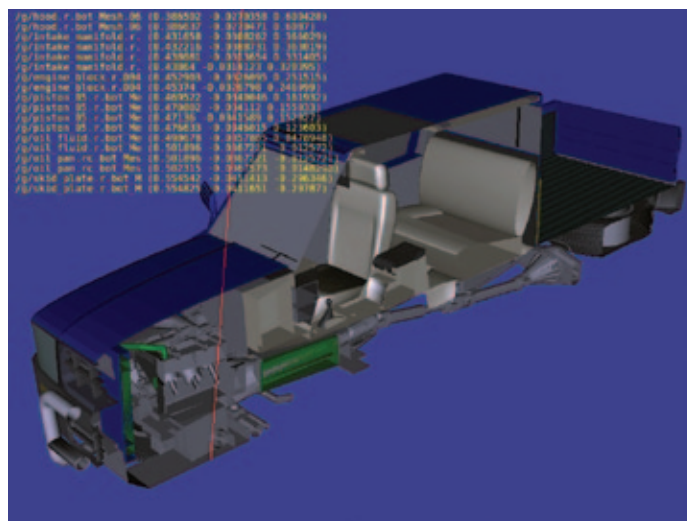
In addition to displaying the shot line visually, VSL provides a list of all objects on the shot line. When interfaced with the Database and Information Management Technique (DIMIT), VSL can also compute system degradation and mission impact resulting from disabling these objects.

Live-fire planning for several major DoD systems have already benefitted from VSL including the Paladin Integrated Management program; the Stryker Nuclear, Biological and Chemical Reconnaissance Vehicle; Stryker Mobile Gun System; and the U.S. Marine Corps Expeditionary Fighting Vehicle. VSL and DIMIT are part of ARL's development of mission-based test and evaluation capabilities under the Paladin Integrated Management program and VSL may also be leveraged in support of the Joint Air-to-Ground Missile System program.

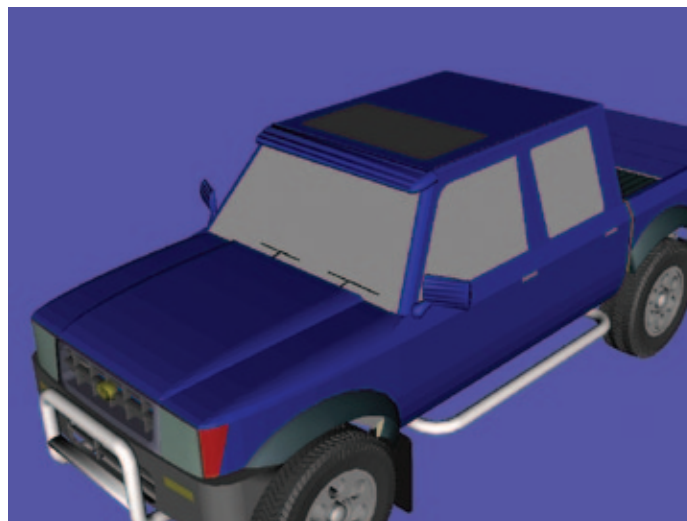
VSL was demonstrated to the DoD evaluation community at the June 2009 National Defense Industry Association Live-Fire Test and Evaluation Conference.



Cutaway view of truck showing shot line.



Screenshot of geometry, shot line, and list of all components along selected shot line.



CAD image of pickup truck.

From the Director

Balancing Current and Future Needs



ARL is working to position and establish itself across scientific disciplines, exploring the next generation of technological breakthroughs while maintaining its strong commitment to provide current support to our Soldiers. The opportunity for the ARL to make a real difference has never been better or more important.

The measure of our success will be our ability to meet the needs of the Soldier both in the near term and into the future (10- to 20-year horizon). Our commitment to support our troops today is unshakable and we will always strive to meet their needs. At the same time, we must maintain a focus on the future. The advancements we make today will not always have immediate impacts, but they provide the necessary building blocks to ensure technological supremacy on an ever-changing battlefield involving different environments, opponents and threats.

The nature of the research we conduct today is unprecedented in its need to be interdisciplinary. The challenges we face mandate collaboration across multiple fields of science and technology. These include emerging areas of bioscience, nanotechnology and neuroergonomics. What we've done over the last few years has been aimed at enabling that interaction.

To facilitate a cross-pollination of ideas and approaches, we have created seven new Strategic Research Initiatives (SRIs) in the areas of materials, neuroscience, network science, computational sciences, electronics, energy science and autonomous systems technology. We corporately invest in innovative, high-risk/ high-payback programs in each SRI. If successful, these programs will become part of our core mission program. One of the criteria for receiving corporate funding under the SRIs is that they must be collaborative efforts across the ARL organization and scientific fields. It is our intent that this requirement for interdisciplinary involvement will expand to include all of our research efforts.

Our focus on the future is immutable and enduring. As the Army's research laboratory, it is up to us to perform the basic and applied research that will lead to end products that will give our Soldiers greater chances for survival and victory on the battlefield in the decades to come.



Glossary

3DWF	3-D Wind Field	DSRC-T	Distributed Survivable Resource Control-Tactical
AC	Alternating Current	EAR	Environment for Auditory Research
ADA CTA	Advanced Decision Architectures Collaborative Technology Alliance	ECoG	Electrocorticography
AFWA	Air Force Weather Agency	EEG	Electroencephalography
AHPCRC	Army High Performance Computing Research Center	EFV	Expeditionary Fighting Vehicle
AMC	Army Materiel Command	EPS	Electromagnetic Protection System
AMRDEC	Aviation and Missile Research, Development and Engineering Center	ESEP	Engineer and Scientist Exchange Program
APG	Aberdeen Proving Ground	FDC	Flexible Display Center
APU	Auxiliary Power Unit	FI	Fragment Impact
ARDEC	Armament Research, Development and Engineering Center	FLOP	Floating-point Operation Performance
ARL	Army Research Laboratory	FPA	Focal Plane Array
ARO	Army Research Office	FPGA	Field Programmable Gate Array
ATO	Army Technology Objective	FY	Fiscal Year
BRAC	Base Realignment and Closure	GNC	Guidance, Navigation, and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance	GPS	Global Positioning System
C&N CTA	Communications and Networks Collaborative Technology Alliance	GPU	Graphics Processing Unit
CAD	Computer Aided Design	HAP	Hazardous Air Pollutant
CBM+	Condition-Based Maintenance Plus	HBCU/MI	Historically Black Colleges and Universities/Minority Institution
CERDEC	Communications-Electronics Research, Development and Engineering Center	HEL	High Energy Laser
CHHPM	U.S. Army Center for Health Promotion and Preventive Medicine	HMMWV	High Mobility Multipurpose Wheeled Vehicle
CISD	Computational and Information Sciences Directorate	HRED	Human Research and Engineering Directorate
CMC	Ceramic Matrix Composite	HUMS	Health and Usage Monitoring Systems
CPU	Computer Processing Units	IAT	Institute for Advanced Technology
C-QWIP	Corrugated Quantum Well Infrared Photodetector	ICB	Institute for Collaborative Biotechnologies
CSLANT	Collaborative SSlide ANnotation Tool	IED	Improvised Explosive Device
CTA	Collaborative Technology Alliance	IM	Insensitive Munitions
DC	Direct Current	IMPRINT	Improved Performance Research Integration Tool
DIMT	Database and Information Management Technique	IP	Intellectual Property
DoD	Department of Defense	IR	Infrared
DRI	Director's Research Initiative	ISN	Institute for Soldier Nanotechnologies
DSI	Director's Strategic Initiative	JAAWIN	Joint Army/Air Force Weather Information Network
DSRC	Defense Supercomputing Resource Center	JCA	Joint Cargo Aircraft
		JIEDDO	Joint Improvised Explosive Device Defeat Organization
		JOA	Joint Ownership Agreement
		JTAPIC	Joint Trauma Analysis and Prevention of Injury in Combat

M-ATV	MRAP All-Terrain Vehicle
MANET	Mobile Ad Hoc Network
MANPADS	Man-portable Air Defense Systems
ManTech	Army Manufacturing Technology
MAWRS	MRAP Armor Weight Reduction Spiral
MBT&E	Mission Based Test and Evaluation
MEAP	MRAP Expedient Armor Program
MEMS	Microelectromechanical Systems
MES	Mechanical Systems Electrospray
MFC	Microbial Fuel Cell
MGS	Mobile Gun System
MIT	Massachusetts Institute of Technology
MONOPATI	Multi-Objective Network Optimization and Assessment Tool
MRAP	Mine Resistant Ambush Protected
MURI	Multidisciplinary University Research Initiative
NBCRV	Nuclear, Biological and Chemical Reconnaissance Vehicle
NCO	Non-Commissioned Officer
NDIA	National Defense Industry Association
NIR	Near Infrared
NRC	National Research Council
NSRDEC	Natick Soldier Research, Development and Engineering Center
NVESD	Night Vision and Electronic Sensors Directorate
ODT	Omni-Directional Treadmill
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OP	Outreach Program
ORA	Organizational Risk Analyzer
P&D	Prognostics and Diagnostics
PEO	Program Executive Office
PILSNER	Proactive Integrated Link Selection for Network Robustness
PIM	Paladin Integrated Management
PM	Program Manager
QD	Quantum Defect
QWIP	Quantum Well Infrared Photodetector
RDEC	Research, Development and Engineering Center

RDECOM	Research, Development and Engineering Command
RDT&E	Research, Development, Test and Evaluation
REF	Rapid Equip Force
RFID	Radio Frequency Identification
RPG	Rocket-propelled Grenade
S&E	Scientists and Engineers
SBIR	Small Business Innovative Research
SD	Sympathetic Detonation
SEDD	Sensors and Electron Devices Directorate
SiC	Silicon Carbide
SLAD	Survivability/Lethality Analysis Directorate
SLV	Survivability, Lethality and Vulnerability
SOCOM	Special Operations Command
SRI	Strategic Research Initiative
STAR	Scalable Technology for Adaptive Response
STTR	Small Business Technology Transfer Program
TARDEC	Tank Automotive Research Development and Engineering Center
TBO	Time-Between-Overhaul
TEBC	Thermal and Environmental Barrier Coating
TFA	Technology Focus Area
TOPS	Thrown Object Protection System
TPW	Technology Planning Workshop
TTA	Technology Transition Agreement
U.K.	United Kingdom
U.S.	United States
UAV	Unmanned Aerial Vehicles
UGS	Unattended Ground Sensors
UGV	Unmanned Ground Vehicles
UH	Utility Helicopter
USMC	United States Marine Corps
VAPP	Very Affordable Precision Projectile
VOC	Volatile Organic Compound
VSL	Virtual Shot Lines
VTD	Vehicle Technology Directorate
WMRD	Weapons and Materials Research Directorate
WSMR	White Sands Missile Range

UTAMS

Unattended Transient Acoustic
Measurement and Signature
Intelligence (MASINT) System

UTAMS is currently supporting operations in both Iraq and Afghanistan. Approximately 30 UTAMS are providing around-the-clock acoustic and signature detection for mortars, rockets, IEDs and snipers.



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